

MODEL 188
4 MHz SWEEP/
FUNCTION GENERATOR



WAVETEK

INSTRUCTION MANUAL
MODEL 188
**4 MHz SWEEP/
FUNCTION GENERATOR**

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WAVETEK®
SAN DIEGO
3045 Balboa Ave. San Diego, CA 92129
P. O. Box 651, San Diego, Calif. 92112
Tel. 714/079-3200 FAX 910-335-0027

Manual Revision: 1/82
Instrument Release: D

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SAFETY

This instrument is wired for earth grounding via the facility power wiring. Do not bypass earth grounding with two wire extension cords, plug adapters, etc.

BEFORE PLUGGING IN the instrument, comply with installation instructions.

MAINTENANCE may require power on with the instrument covers removed. This should be done only by qualified personnel aware of the electrical hazards.

The instrument power receptacle is connected to the instrument safety earth terminal with a green/yellow wire. Do not alter this connection. (Reference  or  stamped inside the rear panel near the safety earth terminal.)

WARNING notes call attention to possible injury or death hazards in subsequent operations.

CAUTION notes call attention to possible equipment damage in subsequent operations.

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SECTION 1

GENERAL DESCRIPTION

1.1 THE MODEL 188





The Wavelek Model 188, 4 MHz Sweep/Function Generator, is a precision source of sine, triangle and square waveforms plus dc voltage. All waveforms are front panel variable from 4 mHz to 4 MHz and can be internally or externally modulated. Frequencies are variable linearly or logarithmically within a frequency range. When used as a sweep generator, an internal ramp generator provides a recurring sweep over a 1000:1 (linear) frequency range or 10,000:1 (logarithmic) frequency range. Output can be continuous or the generator can be triggered or gated by an external signal or a front panel switch. Amplitude of the waveforms is variable from 10V peak-to-peak into 50 Ω down to 15 mV peak-to-peak. DC reference of the waveform can be offset positively or negatively.

The two selectable waveform outputs are a 20V peak-to-peak maximum and a 2V peak-to-peak maximum (20 dB down from 20 Vp-p); both may be varied over a 30 dB range. Auxiliary outputs are a TTL level sync, a 600 Ω sweep ramp and a 600 Ω generator control voltage signal whose level is proportional to the main generator frequency.

1.2 SPECIFICATIONS

1.2.1 Versatility

Waveforms

Sine , triangle , square , TTL pulse , and dc.

Operational Modes

Continuous: Generator runs continuously at selected frequency.

Triggered: Generator is quiescent until triggered by external signal or manual trigger, then generates one complete waveform cycle at selected frequency.

Gated: As triggered mode, except output continues for duration of gate signal. Last waveform started is completed.

Sweep: An internal ramp generator will sweep the main generator from a lower, start frequency to a higher stop frequency, linearly (3 decades) or logarithmically (4 decades).



Sweep Stop: Frequency switches to high sweep limit. Used to set high frequency limit.

Frequency Range

0.004 Hz linear (0.0004 Hz log) to 4 MHz in 7 overlapping decade ranges:

| | |
|---------------|------------------------|
| $\times 1$ | 0.004 (0.0004) to 4 Hz |
| $\times 10$ | 0.04 (0.004) to 40 Hz |
| $\times 100$ | 0.4 (0.04) to 400 Hz |
| $\times 1K$ | 4 (0.4) Hz to 4 kHz |
| $\times 10K$ | 40 (4) Hz to 40 kHz |
| $\times 100K$ | 400 (40) Hz to 400 kHz |
| $\times 1M$ | 4 (0.4) kHz to 4 MHz |

Function Output

, , selectable and variable to 20 Vp-p (10 Vp-p into 50 Ω) HI output, and to 2 Vp-p (1 Vp-p into 50 Ω) LO output. Both outputs varied with a 30 dB vernier. Peak output current is 100 mA maximum (HI output) into 50 Ω (200 mA peak into a short circuit). Source impedance is 50 Ω .

DC Offset and DC Output

Waveform offset and dc output selectable and variable through HI and LO BNC outputs. DC output selectable by not selecting a waveform function. HI output is $\pm 10V$ max ($\pm 5V$ into 50 Ω) as offset or Vdc output. Signal-peak plus offset limited to $\pm 10V$ ($\pm 5V$ into 50 Ω). LO output is $\pm 1V$ max ($\pm 0.5V$ into 50 Ω) as is signal-peak plus offset limit. DC offset plus waveform attenuated proportionately at LO (-20 dB) output.

TTL Sync Output

TTL pulse (50% duty cycle) at generator frequency. Drives up to 20 TTL loads.

GCV — Generator Control Voltage

0 to 4.0V open circuit output from 600 Ω source impedance. Proportional to frequency of main generator. For use as a horizontal drive signal.

VCG — Voltage Controlled Generator

Up to 1000:1 frequency change (linear mode) or up to 10,000:1 change (logarithmic mode) with external 0 to $\pm 4V$ signal. Upper and lower frequencies limited to maximum and minimum of selected range.

Slew Rate: 2% of range per μs (linear); 0 to 100% of range in 20 ms (logarithmic).

Linearity: $\pm 0.5\%$ through $\times 100K$ range; $\pm 2\%$ on $\times 1M$ range.

Input Impedance: 2 k Ω .

Sweep

Main generator is frequency modulated by internal sweep generator. Main generator frequency repeatedly rises from frequency set by dial and range button to frequency set by sweep stop knob.

Sweep Mode: Linear (3 decades max) or logarithmic (4 decades max).

Sweep Rate: 30 ms to 1 min. (nominal) continuously adjustable.

Sweep Width: Up to 1:1000 (linear) or 1:10,000 (logarithmic) continuously adjustable.

Sweep Output

Ramp waveform output with 4V peak into open circuit. Source impedance 800 Ω . For use as a horizontal drive signal.

Trigger and Gate

Input: TTL compatible levels.

Pulse Width: 50 ns minimum.

Repetition Rate: 4 MHz maximum.

1.2.2 Frequency Precision

Dial Accuracy

$\pm 5\%$ of full scale.

Time Symmetry

Square wave variation from 0.2 to 4.0 on dial less than: $\pm 1\%$ to 100 kHz; $\pm 5\%$ to 4 MHz.

1.2.3 Amplitude Precision

Sine variation with frequency less than: ± 0.2 dB on all ranges through $\times 100K$; ± 1.0 dB to 4 MHz.

1.2.4 Waveform Characteristics

Sine Distortion

Less than: 0.5% on $\times 1K$ and $\times 10K$ ranges; 1% on $\times 1$, $\times 10$, $\times 100$ and $\times 100K$ ranges. All harmonics 25 dB below fundamental on $\times 1M$ range.

Triangle Linearity

Greater than 99% to 200 kHz.

Square Wave Rise and Fall Time

At HF output, less than 50 ns for 10 Vp-p output into 50 Ω termination.

1.2.5 General

Environmental

Specifications apply at 25°C $\pm 5^\circ C$. Instrument will operate from 0°C to 50°C ambient temperatures.

Dimensions

28.6 cm (11 1/4 in.) wide; 8.9 cm (3 1/2 in.) high; 26.7 (10 1/2 in.) deep.

Weight

2.7 kg (6 lb) net; 4.5 kg (10 lb) shipping.

Power

90 to 128V or 198 to 264V (specify); 48 to 66 Hz; less than 15 watts.

NOTE

All specifications apply for dial between 0.2 and 4.0; amplitude at 10 Vp-p from HF output into 50 Ω termination.

SECTION 2

INSTALLATION

2.1 MECHANICAL INSTALLATION

After unpacking the instrument, visually inspect all external parts for possible damage to connectors, surface areas, etc. If damage is discovered, file a claim with the carrier who transported the unit. The shipping container and packing material should be saved in case reshipment is required.

2.2 ELECTRICAL INSTALLATION

2.2.1 Power Connection

WARNING

To preclude injury or death due to shock, the third wire earth ground must be continuous to the facility power outlet. Before connecting to the facility power outlet, examine extension cords, auto-transformers, etc., between the instrument and the facility power outlet for a continuous earth ground path. The earth ground path can be identified at the plug on the instrument power cord; of the three terminals, the earth ground terminal is the nonmatching shape, usually cylindrical.

CAUTION

To prevent damage to the instrument, check for proper match of line and instrument voltage and proper fuse type and rating.

NOTE

Unless otherwise specified at the time of purchase, this instrument was shipped from the factory for operation on a 90 to 128 Vac line supply and with a 1/4 amp slow blow fuse. Instruments configured for 160 to 256 Vac have a 1/8 amp slow blow fuse.

Select the appropriate fuse and 115 or 230 switch position at the rear panel when changing power sources.

2.2.2 Signal Connections

Use 3 foot RG58U 50 Ω shielded cables equipped with BNC connectors to distribute all input and output signals.

2.3 ELECTRICAL ACCEPTANCE CHECK

This checkout procedure is a general verification of generator operation. Should a malfunction be found, refer to the warranty in the front of this manual.

A two channel oscilloscope, four 3 foot 50 Ω coax cables with BNC connectors, a coax tee connector and an additional function generator are required for this procedure.

Preset the generator front panel controls as follows:

| Control | Position |
|----------------------|-----------------|
| Dist | 2.0 |
| MODE | CONT (released) |
| FUNCTION | Γ_L |
| DC OFFSET | OFF (ccw) |
| AMPLITUDE | MAX (cw) |
| FREQUENCY MULTIPLIER | x 1K |
| SWEEP | CONT (released) |

Set up the oscilloscope, Model 168 and external function generator as shown in figure 2-1 and perform the steps in table 2-1.

2.4 CHANGING THE OUTPUT IMPEDANCE

The output impedance is normally

HI 10V p-p (50 Ω source) into 50 Ω .
LO 1V p-p (50 Ω source) into 50 Ω .

If simultaneous 6000 and 500 output impedances are desired

1. Change value of R148 from 499 Ω to 604 Ω .
2. Remove R149

The result is

Hi: 10V p-p (50 Ω source) into 50 Ω .
 LD: 10V p-p (600 Ω source) into 600 Ω .

Amplitude is variable over 30 dB. Square wave rise and fall time is less than 150 ns. Any value greater than 6000 may also be substituted for the value of R148 for other output impedances.

To increase the range of the variable amplitude control in a modified unit beyond 30 dB, decrease the value of R124 as necessary. Waveform quality relative to the standard unit is not guaranteed below -30 dB and above 20 kHz.

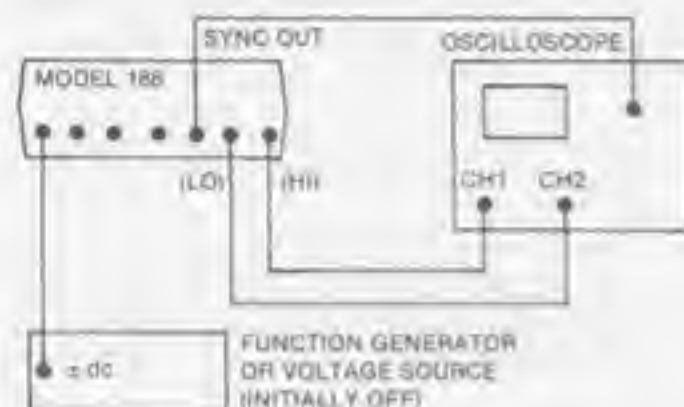


Figure 2-1. First Setup

Amplitude is normally variable over 30 dB for each output with a 50 dB amplitude range available by utilizing both outputs.

Table 2-1. Initial Checkout

| Step | Control | Position/Operation | Observation |
|------|---|---|---|
| 1 | POWER | ON | $\pm 10V$ square wave on CH1 and $\pm 1V$ on CH2. Return to CH1 only. |
| 2 | Dial | Rotate in both directions. Return to 2.0 | Rotation cw increases frequency of \square , rotation ccw decreases frequency. |
| 3 | FREQUENCY MULTIPLIER | Press each switch sequentially, return to $\times 1X$. | Frequency increases in decade steps, left to right. |
| 4 | AMPLITUDE | Rotate ccw | Amplitude decreases. |
| 5 | DC OFFSET | Rotate cw. Return to OFF | Output immediately offset negative, then moves positive. OFF return it to original level. |
| 6 | AMPLITUDE | Rotate cw. | Square returns to original amplitude. |
| 7 | Function Generator or DC Voltage Source | Vary input dc voltage, then disconnect VCG IN input. | Frequency increases with positive voltage and decreases with negative voltage. |
| 8 | FUNCTION | Press $\sqrt{}$, \square , \wedge | Observe $\sqrt{}$, \square , \wedge waveforms. |
| 9 | MODE | Gate (CONT depressed, TRIG/GATE released). | A dc level near zero volts (except \square function). |
| 10 | MANUAL TRIGGER | Press and hold | Continuous $\sqrt{}$. |

Table 2-1. Initial Checkout (Continued)

| Step | Control | Position/Operation | Observation |
|---|---------------|---|---|
| <i>Set up trigger source as shown in figure 2-2. Set trigger source for 100 Hz TTL signal</i> | | | |
| 11 | — | — | gated on during positive portion of TTL signal on CH2 |
| 12 | TRIG/GATE | Trigger (depressed) | One cycle per trigger cycle |
| 13 | MODE | Main generator continuous (CONT released) | Setup connectors as shown in figure 2-3. Sync scope on channel 2 input. |
| 14 | Dial | Full cw | |
| 15 | SWEEP Control | Linear sweep (CONT depressed, SWP/STOP depressed, LOG/IN extended, STOP full cw, TIME centered) | Output varies from low frequency to high frequency |
| 16 | LN/LOG Button | Press | Logarithmic distributed sweep when compared to step 15 linear sweep |

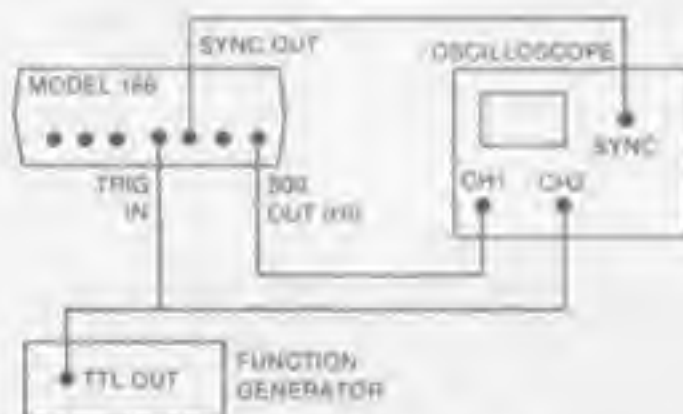


Figure 2-2. Second Setup

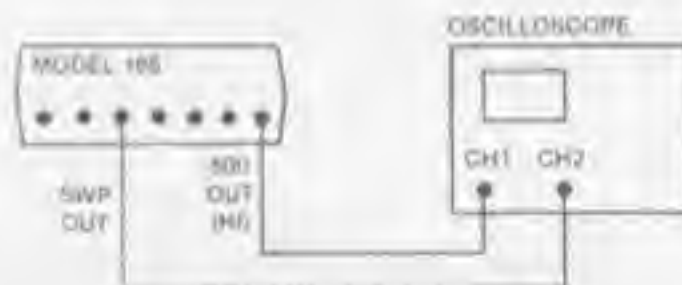


Figure 2-3. Third Setup

SECTION 3

OPERATION

3.1 CONTROLS AND CONNECTIONS

The generator front panel controls and connectors are shown in figure 3-1 and keyed to the following descriptions.

- 1 **Frequency Dial** — Settings under the dial index mark summed with **21** and multiplied by **4** determine the output signal frequency and the sweep start frequency in sweep mode. This dial is engraved with both linear and logarithmic scales; outer scale linear and inner scale logarithmic.
- 2 **POWER Button** — Turns generator ON and OFF.
- 3 **STOP Knob** — Sets the upper frequency limit when **CONT 6** is depressed and **SWP/STOP 6** is extended.
- 4 **FREQUENCY MULTIPLIER Controls** — Selects one of seven frequency multipliers for dial **1** setting.
- 5 **CONT Button** — Selects sweep submode to main generator's continuous mode. Extended is continuous (nonsweep) mode while depressed is sweep mode. Sweep is from a low frequency set by **1** to a high frequency set by **3**. Main generator mode control **8** must be in continuous mode (extended).
- 6 **SWP/STOP Button** — When button is depressed (and **5** depressed and **8** extended) selects repetitive sweep of the main generator frequency. When button is extended, the frequency is stopped at the upper sweep limit with upper frequency being set by **STOP** control **3**.
- 7 **LIN/LOG Button** — Selects linear or logarithmic frequency distribution of sweep.

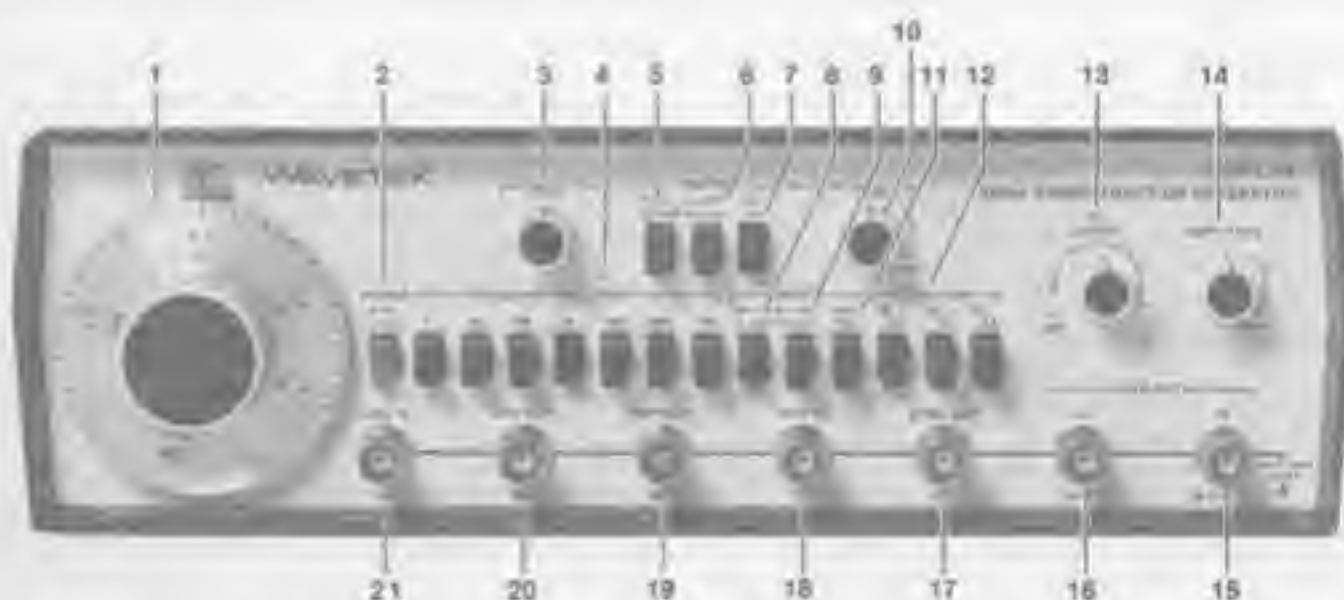


Figure 3-1. Controls and Connectors

VCG and main dial within a frequency range. Linear operation is selected when the button is extended. Logarithmic operation is selected when the button is depressed.

8, 9 Generator MODE Controls — Selects one of the following three modes:

CONT — **8** released. Continuous output at 50Ω OUT **15** and **16** and SYNC OUT (TTL) **17** connectors.

TRIG — **8** and **9** pressed. DC level output until generator triggered by the MAN TRIG **11** or with a signal at the TRIG IN connector **18**. When triggered, the generator output is one cycle of waveform followed by a dc level.

GATE — **8** pressed and **9** released. As for TRIG except the output is continuous for the duration of the manual or external trigger signal. The last cycle started is always completed.

10 TIME Knob — Sets the sweep time by controlling the period of the sweep ramp generator.

11 Manual Trigger Button — Triggers or gates the output signals when generator mode is TRIG or GATE (**8** pressed). In trigger mode, one waveform cycle is output when the button is pushed. In gate mode, waveform cycles are continuously output as long as the button is held in.

12 FUNCTION Selector — Selects one of three waveforms or when all three buttons are released, a dc level.

13 DC OFFSET Control — Offsets the 50Ω OUT waveforms or gives dc levels from -10V to +10V (-5V to +5V into 50Ω) at **15** and from -1V to +1V (-0.5V to +0.5V into 50Ω) at **16**. An OFF position ensures no offset.

14 AMPLITUDE Control — Clock rotation reduces waveform amplitudes at **15** and **16** by 30 dB. DC and offset voltages are not affected by this control.

15 50Ω OUT HI Connector — The main output of the generator at the function selected. Maximum 20 Vp-p (10 Vp-p into 50Ω) with 30 dB continuous amplitude control. 50Ω source impedance.

16 50Ω OUT LO Connector — Same as **15** except 20 dB (1/10) lower in amplitude.

17 TTL OUT Connector — A TTL square for each cycle of the generator. To be used for synchronization or as a TTL signal capable of driving 20 TTL loads.

18 TRIG IN Connector — Accepts a TTL signal to trigger or gate the generator. Triggers on the rising (low to high) transition and gates during the positive (high) portion of the triggering signal.

19 SWP OUT Connector — Supplies a ramp waveform with an approximate 4V peak into an open circuit. For use as a horizontal drive signal. Source impedance is 800Ω.

20 GCV OUT Connector — Provides a 0 to 4V open circuit output proportional to the frequency of the main generator. For use as a horizontal drive signal. Source impedance is 600Ω.

21 VCG IN Connector — Accepts ac or dc voltages to proportionately control frequency within the range determined by the FREQUENCY MULTIPLIER **4**. Positive voltage increases the frequency set by the dial **1**; negative voltage decreases the frequency. The VCG IN will not drive the generator frequency beyond the normal dial limits of a range. Input impedance is 2 kΩ.

3.2 OPERATION

Perform the initial checkout in Section 2 for the 106 of the instrument. Any questions concerning individual controls and connectors may be answered in paragraph 3.1.

3.2.1 Signal Termination

Proper signal termination, or loading, of the generator connectors is necessary for its specified operation. For example, the proper termination of either of the 50Ω OUT connectors is shown in figure 3-2. Placing the 50Ω terminator, or 50Ω resistance, in parallel with a higher impedance, matches the receiving instrument input impedance to the coax characteristic and generator output impedance, thereby minimizing signal reflection or power loss on the line due to impedance mismatch.

The input and output impedances of the generator connectors are listed below.

| Connector | Impedance |
|----------------|-----------|
| 50Ω OUT (HI) | 50Ω |
| 50Ω OUT (LO) | 50Ω |
| SYNC OUT (TTL) | * |
| TRIG IN | * |
| VCG IN | 2kΩ |
| SWP OUT | 600Ω |
| GCV OUT | 600Ω |

*The TTL OUT connector is diode protected and can drive up to 20 Transistor-Transistor-Logic (TTL) loads (low level between 0V and 0.4V, and high level between 2.4V and 5V). It should not be connected to resistive load less than 600Ω. The TRIG IN connector accepts TTL logic levels, is diode protected, and requires 500 μ A drive from a high level output.

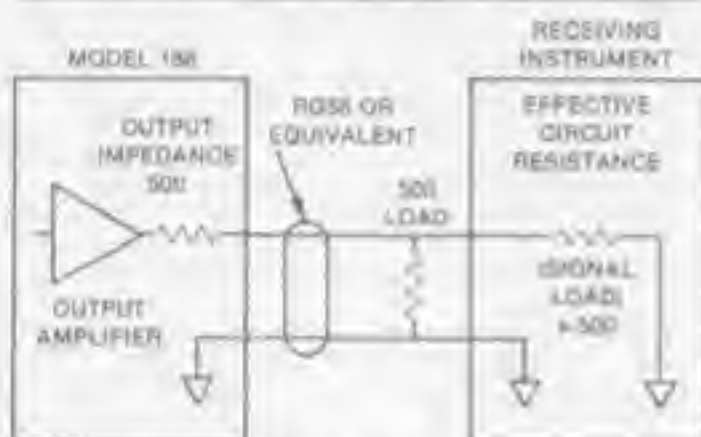


Figure 3-2. Signal Termination

3.2.2 Manual Function Generator Operation

For basic operation, select the waveform frequency and amplitude. The following steps demonstrate manual control of the function generator. (Bold numbers are keyed to figure 3-1.)

| Step | Control/Connector | Setting |
|------|-------------------------------|---|
| 1 | 50Ω OUT 15 16 | Connect circuit to either output (refer to paragraph 3.2.1) |
| 2 | FREQUENCY MULTIPLIER 4 | Set to desired range of frequency |
| 3 | Frequency Dial 1 | Set to desired frequency within the range |
| 4 | SWEEP's CONT 5 | Extended |

| | | |
|---|---------------------|--|
| 5 | FUNCTION 12 | Set to desired waveform. |
| 6 | DC OFFSET 13 | Set as desired. Limit waveform amplitude to prevent clipping (see figure 3-3). |
| 7 | AMPLITUDE 14 | Set for desired amplitude. |

3.2.3 Voltage Controlled Function Generator Operation

Operation as a voltage controlled function generator (VCG) is as for a manually controlled function generator, only the frequency within a particular range is additionally controlled by an external voltage ($\pm 4V$ excursions) injected at the VCG IN connector. Perform the steps given in paragraph 3.2.2, only set the frequency dial to determine a reference from which the frequency is to be voltage controlled.

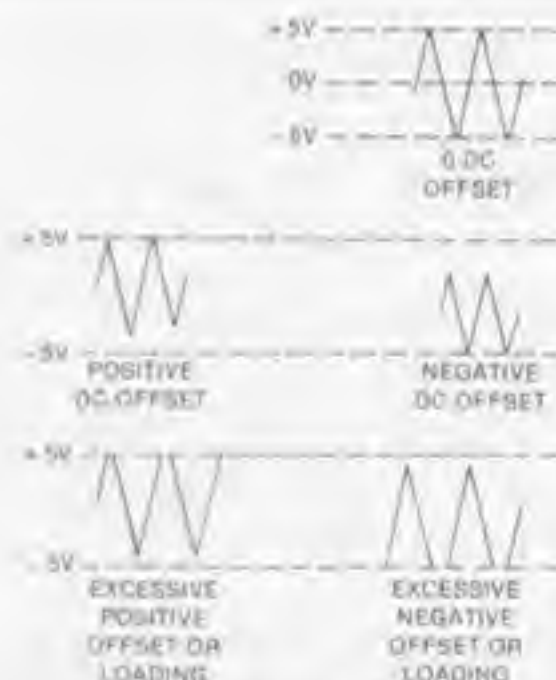


Figure 3-3. DC OFFSET Control

- For frequency control with positive dc inputs at VCG IN, set the dial for a lower frequency limit.
- For frequency control with negative dc inputs at VCG IN, set the dial for an upper frequency limit.
- For modulation with an ac input at VCG IN, set the dial at the desired center frequency. Do not

exceed the limits of the selected frequency range.

Figure 3-4 is a nomograph with examples of dial and voltage effects. Example 1 shows that with 0V VCG input, frequency is determined by the main dial setting, 2 (linear mode) or .04 (logarithmic mode) in this example. Example 2 shows that with a positive VCG input, output frequency is increased. Example 3 shows that with a negative VCG input, output frequency is decreased. (Note that the Output Frequency Factor column value must be multiplied by a frequency range multiplier to give the actual output frequency.)

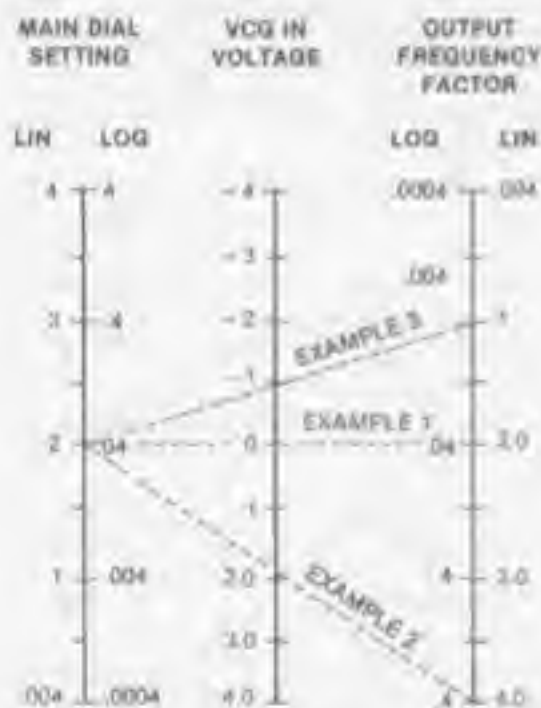


Figure 3-4. VCG Voltage-to-Frequency Nomograph

NOTE

Nonlinear operation may result when the VCG input voltage is excessive; that is, when the attempted generator frequency exceeds the range limits. The upper limit is four times the multiplier setting, and the lower limit is 1/1000th (linear) or 1/10,000 (logarithmic) of the upper limit.

The up to 1000:1 (linear) or 10,000:1 (logarithmic) VCG sweep of the generator frequencies available in each range results from a 4V excursion at the VCG IN connector. With the Frequency dial set to 4.0, excursions between -4V and 0V at VCG IN provide the up to 1000:1 (lin) or 10,000:1 (log) frequency sweep. With the dial set to .004 (linear) or .0004 (logarithmic), excursions between 0V and +4V at the VCG IN provide up to 1000:1 (linear) or 10,000:1 (logarithmic) sweep within the set frequency range.

3.2.4 Sweep Generator Operation

Operation as a sweep generator is similar to manually controlled generator operation except the main generator can be repetitively swept between two selected frequencies either linearly or logarithmically at a selected sweep rate. The relationship of internal ramp and main generator is shown in figure 3-5.

The following steps describe the sweep operation setup.

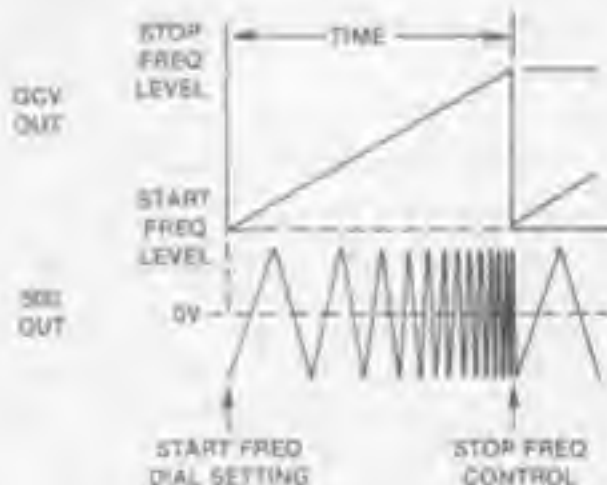


Figure 3-5. Effect of Sweep Time and Width on Output Frequency

| Step | Control | Setting |
|------|-------------|--|
| 1 | MODE CONT 8 | Press to release. (Continuous mode of main generator is necessary for sweep.) |

| Step | Control | Setting |
|------|------------------|---|
| 2 | Frequency dial 1 | Select sweep start frequency |
| 3 | SWEEP's CONT 5 | Depressed. (Selects sweep submode of main generator's continuous operation.) |
| 4 | SWP/STOP 6 | Press to release. (Extended allows setting of stop frequency.) |
| 5 | STOP 3 | Select the stop frequency. (The stop frequency will always be higher than the start frequency.) |
| 8 | Time 10 | Set the internal sweep rate |

3.2.5 Waveforms

Waveform timing for each mode of operation is shown in figure 3-5.

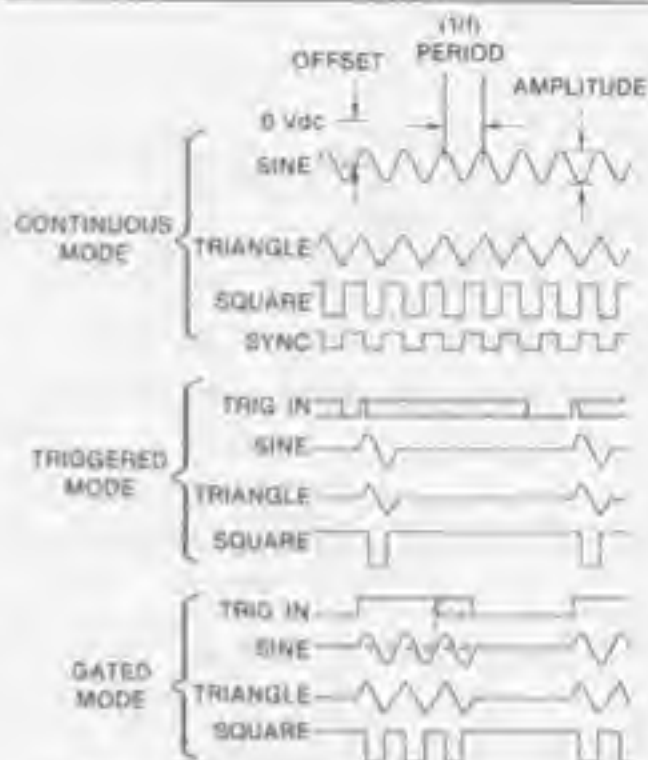


Figure 3-5. Waveform Characteristics

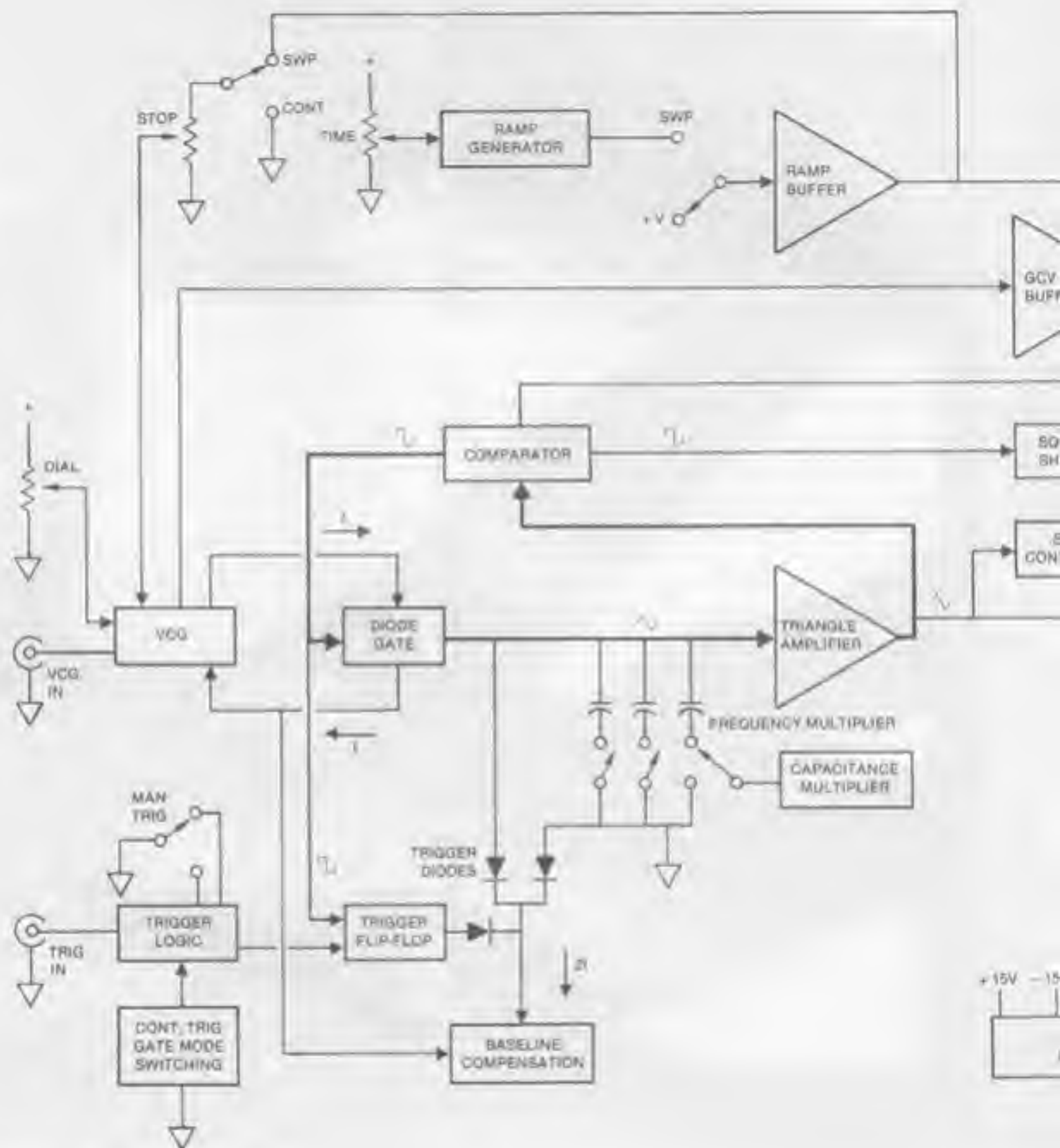
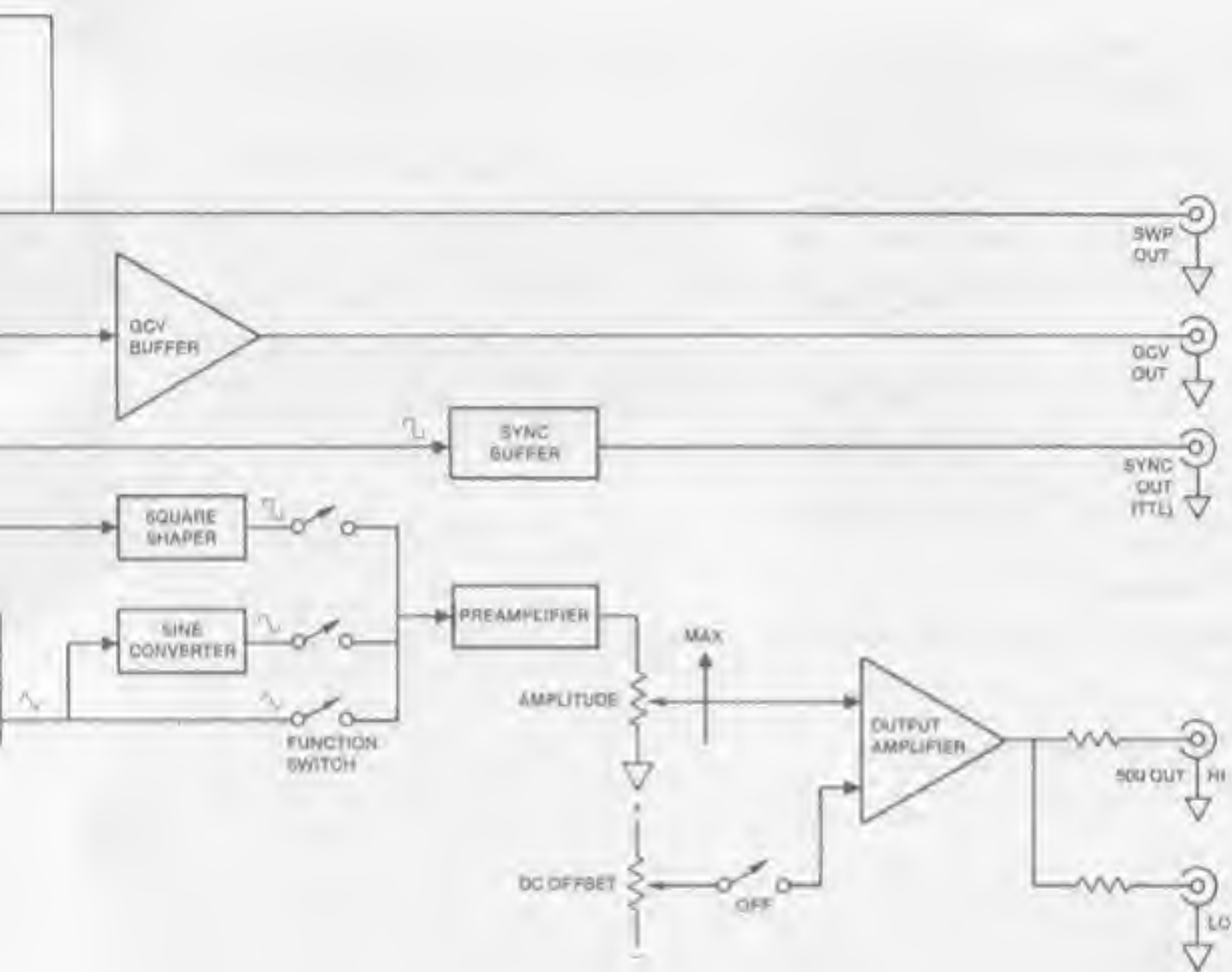


Figure 4-1. Function Block Diagram



SECTION 4

CIRCUIT DESCRIPTION

This section describes the functions of major circuit elements and their relationships to one another as shown in figure 4-1, functional block diagram. The following sections in this manual provide more detailed information for maintaining the instrument.

As shown in figure 4-1, the VCG (Voltage Control of Generator) sums voltage inputs from the frequency dial and the VCG IN connector. This sum voltage controls the magnitude of a complementary current source and current sink. This current varies linearly from approximately 2 mA to 2 μ A over a 1000:1 (4.0 to 004) range or logarithmically from approximately 2 mA to 0.2 μ A over a 10,000:1 (4.0 to 0004) range of each frequency multiplier. The VCG also controls the trigger baseline compensation circuit, which consists of another current sink at twice the current magnitude.

The diode gate, controlled by the comparator output, connects either the current source or the current sink to the timing capacitor selected by the frequency multiplier. When the current source is switched in, the charge on the timing capacitor will rise linearly, producing the positive-going triangle slope. Likewise, the current sink produces the negative-going triangle slope.

The triangle amplifier is a unity gain amplifier whose output is fed to the comparator and to the output circuits. The comparator operates as a window detector with limit points set to the triangle peaks. The ± 2 V output is sent back to the diode gate and to the output circuits. When the output is +2V, the triangle is positive-going until the +1.25V limit is reached and the comparator output switches to -2V. When the output is -2V, the triangle is negative-going until the -1.25V limit is reached and the comparator output switches back to +2V, repeating the process. In this manner, the basic function generator loop, the bold path in figure 4-1, produces simultaneous generation of triangle and square waves at the same frequency.

The output frequency is determined by the magnitude

of the timing capacitor selected by the frequency multiplier switches and by the magnitude of the currents supplied to and removed from it. Since the currents are linearly proportional to the sum of the VCG inputs, so will be the output frequency.

To extend the lower frequency capability of the generator, a capacitance multiplier circuit divides VCG currents by 10 (effectively multiplying the timing capacitor by 10) for each of the lower 3 multiplier ranges.

The TTL square from the comparator is buffered and sent to the SYNC OUT TTL connector. The other side is sent to the trigger flip-flop and to a level shifter to produce the ± 2 V bipolar square for the diode gate and the square shaper circuits. The square shaper converts the square into a current signal and applies it to the F_1 FUNCTION switch. The buffered triangle is applied to the F_2 FUNCTION switch and to the sine converter input. The sine converter, using the nonlinear characteristics of its diodes, converts the triangle into a sinusoidal current for the F_3 FUNCTION switch.

The selected function is sent to the preamplifier, where it is inverted and buffered. The preamplifier output goes to the output amplifier through the AMPLITUDE control where it is summed with offset voltage from the DC OFFSET control. Here, waveform and offset are inverted and amplified to a ± 10 V peak signal which can drive a 50 Ω termination from a 50 Ω source impedance. The output amplifier drives the 50 Ω OUT HI connector and a resistor divider producing the 50 Ω OUT LO output.

Noncontinuous modes of operation (trigger and gate) result from allowing or preventing the VCG current source from charging the timing capacitor. Whenever the trigger flip-flop output is low, each of the two trigger diodes conduct a current I , sourcing $2I$ to the baseline compensation circuit. This removes the current I from the VCG current source and forces a 0V baseline at the triangle amplifier input.

When the CONT switch is released, trigger logic is inhibited from passing any trigger signals and the trigger flip-flop output is held high. This prevents the trigger diodes from conducting and the generator loop operates continuously.

When the CONT switch is pressed, the generator loop is held at the 0V baseline. Pressing the TRIG/GATE switch puts the instrument in triggered mode and any external or manual trigger signals at the trigger logic input will be transformed into a narrow pulse corresponding to the low-to-high transition of the trigger input. This pulse sets the trigger flip-flop high and allows the generator loop to run. When the triangle negative peak is reached, the comparator low-to-high transition clocks the trigger flip-flop low and, when the 0V baseline level is reached, the generator loop again stops. The result is a single cycle generated after the triggering signal corresponding to 0 to 360° of phase. Successive triggered waveforms always start at the same 0° point.

Releasing the TRIG/GATE switch puts the instrument in the gated mode. This is identical to the triggered mode, except the trigger flip-flop is held high for the full duration of the triggering signal. The generator produces continuous waveforms during the time the external signal is high or the manual trigger switch is

held in. The last triggered cycle started is always completed and successive gated bursts always start at the 0° point.

When sweep mode is selected by a combination of the main generator in continuous mode and the ramp generator switches set to SWP, the ramp generator is enabled and a ramp voltage becomes part of the control voltage in the VCG circuit to control the main generator frequency. Ramp period, variable from 30 ms to 1 minute, is set by the TIME Control. Ramp generator output is buffered to drive the sweep output and VCG circuit. The ramp magnitude supplying the VCG input is controlled by the STOP potentiometer.

Selecting the stop switch position biases the buffer amplifier to a level equal to the positive peak of the ramp (+V). In this static mode the upper sweep limit can be set by the STOP Control.

When the CONT position of the SWEEP switch is selected the ramp generator is disabled and the buffered ramp is disconnected from the VCG input.

The GCV (Generator Control Voltage) from the VCG circuit is a resultant voltage from the three VCG inputs: dial VCG IN and sweep ramp. This voltage is buffered and made available at the GCV BNC.

SECTION 5

ALIGNMENT

5.1 FACTORY REPAIR

Wavetek maintains a factory repair department for those customers not possessing the necessary personnel or test equipment to maintain the instrument. If an instrument is returned to the factory for alignment or repair, a detailed description of the specific problem should be attached to minimize turnaround time.

5.2 REQUIRED TEST EQUIPMENT

Voltmeter: Millivolt dc measurement (1% accuracy)
 Oscilloscope: ≥ 60 MHz bandwidth
 Counter: 4 MHz (0.1% accuracy)
 50 Ω Feedthru: $\pm 1\%$ accuracy, 2W
 Distortion Analyzer: To 400 kHz
 RS58U Coax Cable: 3 ft length BNC male contacts

5.3 REMOVING GENERATOR COVERS

1. Invert the instrument and remove the four screws in the bottom cover.
2. Turn the instrument upright; remove the top cover for access to generator alignment controls.
3. When alignment is complete, secure the bottom cover with four screws.

NOTE

Remove the cover only when it is necessary to make adjustments or measurements.

5.4 ALIGNMENT

After referring to the following preliminary data, perform alignment, as necessary, per table 5-1. If performing partial alignment, check previous settings and adjustments for applicability. See figures 5-1 and 5-2 for alignment control location.

1. All measurements made at the FUNCTION OUT connector must be terminated into a 50 Ω ($\pm 1\%$) load.
2. Start the alignment by connecting the unit to an appropriate ac power source and setting the front panel switches as follows:

| | |
|----------------|-----------------|
| POWER | ON |
| Frequency Dial | 4.0 |
| FREQ MULT (Hz) | $\times 1K$ |
| MODE/CONT | CONT (released) |
| FUNCTION | Γ |
| DC OFFSET | OFF |
| AMPLITUDE | MAX |
| LIN/LOG | LIN (released) |
| SWEEP's CONT | CONT (released) |
| SWP/STOP | STOP (released) |

3. Allow the unit to warm up at least 30 minutes for final alignment. Keep the instrument cover on to maintain heat. Remove cover only to make adjustments or measurements.

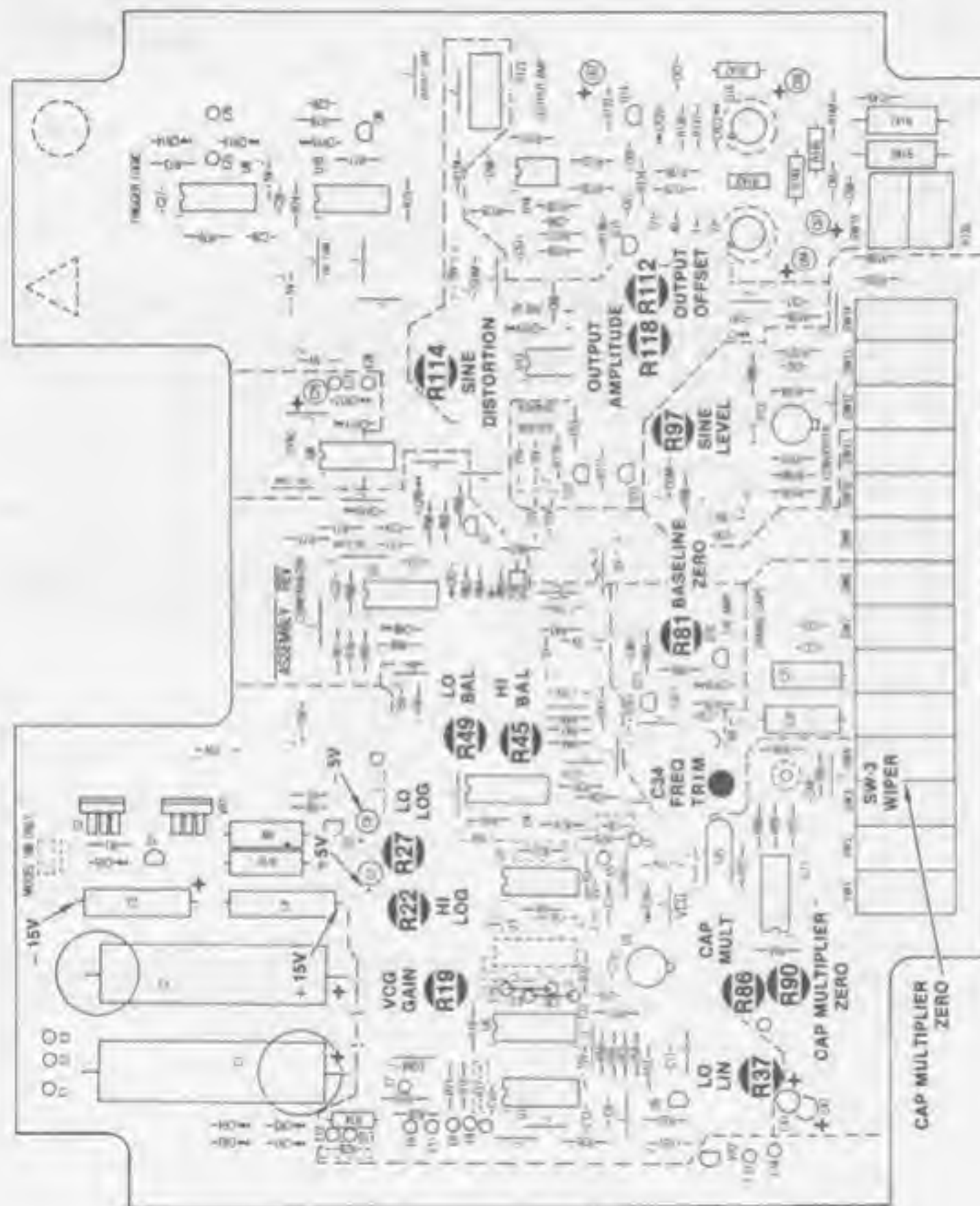


Figure 5-1. Alignment Point Location, Generator Board

Table 5-1. Alignment Procedure

| Step | Check | Tester | Test Point | Control Setting | Adjust | Result | Remark |
|------|--|-----------|---------------------------------|-------------------------------------|-------------------|----------------------------------|---|
| 1 | Power Supply | Voltmeter | C4 + | Paragraph 5.4, Step 2 | | +15 \pm .75V | Verify \pm 15V should track within 30 mV |
| 2 | | | C5 - | | | -15 \pm .75V | |
| 3 | | | C7 + | | | +5 \pm .25V | Verify |
| 4 | | | C6 - | | | -5 \pm .25V | |
| 5 | Capacitor Multiplier Zero | | SW3 - B Wiper | | R90 CAP MULT ZERO | 0 \pm 2V | |
| 6 | Approximate Bottom of the Dial Frequency | Counter | 509 OUT Hi (terminate into 509) | Dial: 004 FREQ MULT: 10K | R37 LO LIN | 20 to 25 ms period | |
| 7 | Bottom of the Dial Symmetry | Scope | | | R49 LO BAL | Equalize (+) and (-) half cycles | Set scope to (-) trigger; display one full cycle. Align positive transition to center of screen. Multiply the horizontal display \times 10. Set scope to (+) trigger; adjust R49 to align negative transition with center of screen |
| 8 | Bottom of the Dial Frequency (Lin) | Counter | | FREQ MULT: \times 1K | R37 LO LIN | 350 (\pm 50) ms period | |
| 9 | Top of the Dial Symmetry | Scope | | Dial: 4.0 | R45 HI BAL | Equalize (+) and (-) half cycles | See step 7 |
| 10 | Top of the Dial Frequency (Lin) | Counter | | Dial: 4.0 FREQ MULT: \times 1K | R19 VCG GAIN | 4 \pm .2 kHz | |
| 11 | | | | FREQ MULT: \times 10K | | 40 \pm 3 kHz | Verify |
| 12 | | | | FREQ MULT: \times 1M | C34 FREQ TRIM | 4 \pm .02 MHz | |
| 13 | | | | FREQ MULT: \times 100K | | 400 \pm 5 kHz | Verify. If necessary, trim by changing value of C33 |
| 14 | | | | FREQ MULT: \times 100 | R86 CAP MULT | 2.5 \pm .05 ms | |

Table 5-1. Alignment Procedure (Continued)

| Step | Check | Tester | Test Point | Control Setting | Adjust | Result | Remark |
|------|------------------------------------|---------------------|------------------------|--|---|-------------------------------|--|
| 15 | | | | FREQ MULT: $\times 10$ | | 25 ± 5 ms | Verify |
| 16 | | | | FREQ: $\times 1$ | | 250 ± 5 ms | |
| 17 | Bottom of the Dial Frequency (Log) | | | Dial: 0004 FREQ MULT: $\times 100K$ SWEEP: CONT, STOP, LOG | R27 LO LOG | 40 ± 2 Hz | Allow 1 hour warm-up |
| 18 | Top of the Dial Frequency (Log) | | | Dial: 4.0 FREQ MULT: $\times 100K$ | R22 HI LOG | 400 ± 10 kHz | Repeat steps 17 and 18 once |
| 19 | Sine Distortion (Lin) | Distortion Analyzer | | FUNCTION: \sim FREQ MULT: $\times 1K$ | R97 SINE LEVEL R114 DISTORTION | Adjust for minimum distortion | It may be necessary to reduce amplitude to 5V peak |
| 20 | Output Amplitude | Scope | | FUNCTION: \sim | R118 OUTPUT AMPL | 10 Vp-p (+3V/-2V) | |
| 21 | Output Offset | Voltmeter | | FUNCTION: \sim | R112 OFFSET | 0 ± 50 mV | |
| 22 | Baseline Zero | Scope | | MODE: Trigger | R81 BASELINE ZERO | 0 ± 75 mV | It may be necessary to trim the baseline with R80 |
| 23 | Sweep Offset | Voltmeter | SWP OUT (Unterminated) | SWEEP: CONT, SWP, LIN | R9 (Sweep board) SWEEP OFFSET | 0 ± 2 mV | |

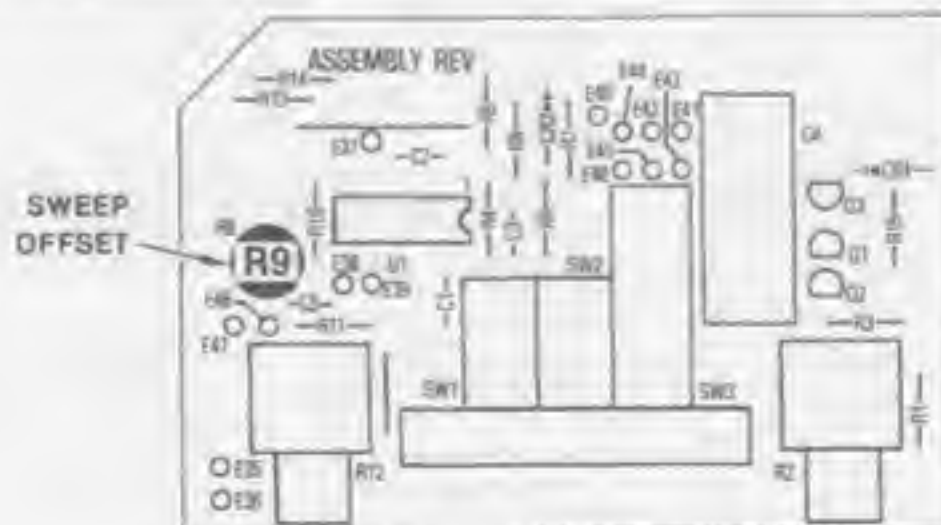


Figure 5-2. Alignment Point Location, Sweep Board

6

SECTION 6

TROUBLESHOOTING

6.1 FACTORY REPAIR

Wavetek maintains a factory repair department for those customers not possessing the necessary personnel or test equipment to maintain the instrument. If an instrument is returned to the factory for alignment or repair, a detailed description of the specific problem should be attached to minimize turnaround time.

6.2 TROUBLESHOOTING TABLES

Table 6-1 gives an index of the troubleshooting tables by indications of common problems. The tables do not cover every possible trouble, but, when used in conjunction with circuit descriptions and schematics, will be an aid in systematically isolating faulty components.

6.3 TROUBLESHOOTING INDIVIDUAL COMPONENTS

6.3.1 Transistor

1. A transistor is defective if more than one volt is measured across its base-emitter junction in the forward direction.
2. A transistor when used as a switch may have a few volts reverse bias voltage across base-emitter junction.
3. If the collector and emitter voltages are the same, but the base-emitter voltage is less than 500 mV forward voltage (or reversed bias), the transistor is defective.
4. A transistor is defective if its base current is larger than 10% of its emitter current (calculate currents from voltage across the base and emitter series resistors).
5. In a transistor differential pair (common emitter stages), either their base voltages are the same in normal operating condition, or the one with less forward voltage across its base-emitter junction should be off (no collector current); otherwise, one of the transistors is defective.

6.3.2 Diode

A diode (except a zener) is defective if there is greater than one volt (typically 0.7 volt) forward voltage across it.

6.3.3 Operational Amplifier

1. The "+" and "-" inputs of an operational amplifier will have less than 15 mV voltage difference when operating under normal conditions.
2. When the output of the amplifier is connected to the "-" input (voltage follower connection), the output should be the same voltage as the "+" input voltage; otherwise, the operational amplifier is defective.
3. If the output voltage stays at maximum positive, the "+" input voltage should be more positive than the "-" input voltage, or vice versa; otherwise, the operational amplifier is defective.

6.3.4 FET Transistor

1. No gate current should be drawn by the gate of an FET transistor. If so, the transistor is defective.
2. The gate-to-source voltage is always reverse biased under a normal operating condition; e.g., the source voltage is more positive than the gate voltage for 2N5485, and the source voltage is more negative than gate voltage for a 2N5462. Otherwise, the FET is defective.
3. If the device supplying gate voltage to an FET saturates, the FET has too large a V_{GS} (pinch off) for the circuit and should be replaced.

6.3.5 Capacitor

1. Shorted capacitors have zero volts across their terminals.

2. Opened capacitor can be located (but not always) by using a good capacitor connected in parallel with the capacitor under test and observing the resulting effect.

6.4 GENERAL INSTRUCTIONS

When encountering a problem, it is advisable to return as many of the front panel controls as possible to their initial settings and still retain the problem. The troubleshooting tables in this section generally begin at these initial settings and specify all subsequent setups. Preset the front panel controls as follows.

| Control | Position |
|----------------|-----------------|
| Frequency Dial | 40 |
| POWER | ON |
| FREQ MULT (Hz) | 1K |
| FUNCTION | △ |
| DC OFFSET | OFF |
| AMPLITUDE | MAX |
| SWEEP | CONT. STOP. LIN |

CAUTION

To prevent damage to components, turn unit off while removing or replacing components, connectors or pc boards.

The suspected malfunctioning condition should be double checked to eliminate the possibility of improper settings or connections. Before attempting fault isolation, the unit should be checked for proper line voltage selection (refer to Section 2). A good visual inspection of the boards and chassis wires for damage or overheating often saves much time.

Once the malfunction is defined, begin the isolation procedure by selecting an indication in table 6-1 which best describes the malfunction and proceed to the referenced troubleshooting table.

Follow through the checks in the troubleshooting table, using schematics and assemblies as a guide. When positive results are not obtained, perform the indicated corrective procedure.

Table 6-1. Fault Isolation

| Indication | Table |
|--|-------|
| 1. Fuse blown, no power indication or no outputs. | 6-2 |
| 2. Function outputs missing or clipped when TTL sync OK. Triangle problem. | 6-3 |
| 3. Sine waveform problem. | 6-4 |
| 4. Square waveform problem. | 6-5 |
| 5. TTL sync output problem. | 6-6 |
| 6. Generator frequency does not respond correctly to dial and VCG input. | 6-7 |
| 7. Waveform symmetry problem. | 6-8 |
| 8. Problem on bottom three ranges only. | 6-9 |
| 9. Generator trigger and gate mode problem. | 6-10 |
| 10. Sweep problem. | 6-11 |

Table 6-2. Power Supplies and Generator Loop

| <i>Indication: Fuse blown, no power indication or no outputs.</i> | |
|---|---|
| Check | Corrective Procedure |
| 1. Set all controls in their initial positions (refer to paragraph 6.4). | Replace fuse; check for normal operation. a. CR1 - CR4. b. C1, C2. c. SW1. d. T1, RV1, F1 (bracket assembly). |
| 2. Ensure line voltage matches instrument configuration (refer to Section 2). Check fuse. | |
| 3. Check C1 (+) and C2 (-) for ± 25 to 26V unregulated dc. | |

Table 6-2. Power Supplies and Generator Loop (Continued)

| <i>Indication: Fuse blown, no power indication or no outputs</i> | |
|--|---|
| Check | Corrective Procedure |
| 4. Check indicator lamp. | DS1 and VR2, wiring E34 and E33. |
| 5. Check Q4 (+) for +15 Vdc. | a. VR1 b. Excessive loading; use board jumpers to isolate cause. |
| 6. Check Q5 (-) for -15 Vdc. | a. Q2 b. U2, Q1 c. Excessive loading; use board jumpers to isolate cause. |
| 7. Check U7 pin 14 for +5 Vdc and U7 pin 13 for -5 Vdc. | a. Q4, Q3, U2 b. Excessive loading; use board jumpers to isolate cause. |
| 8. Check U4 pin 6 for a dc shift from approximately +10V to +15V as the frequency dial is rotated from 4.0 to .004. Check U6 pin 8 for a dc shift from -10V to -15V as the frequency dial is rotated from 4.0 to .004. | Go to table 6-7. |
| 9. Check anode CR6 for approximately +5.5 Vdc. | Go to table 6-10. |
| 10. If emitter Q11 has a 4 kHz, $\pm 1.25V$ triangle, go to table 6-3. | |
| 11. Check for the same voltage at the gate of Q9 as at the emitter of Q11, within saturation limits of the amplifier. | Q9 - Q11 and associated circuitry. |
| 12. If the voltage at the emitter of Q11 is $\approx +1.25V$, check cathode CR10 for approximately -2.5V. If the voltage at the emitter of Q11 is $\approx -1.25V$, check cathode CR10 for approximately +2.5V. | U7, Q7 and associated circuitry. |
| 13. Check U5. | |

Table 6-3. Output Circuits

| <i>Indication: Function outputs missing or clipped when TTL sync output OK. Problem with triangle waveform.</i> | |
|---|---|
| Check | Corrective Procedure |
| 1. Set controls to initial positions (refer to paragraph 6-4). | Check for normal operation. |
| 2. Check emitter Q11 for a 4 kHz, $\pm 1.25V$ triangle. | Go to table 6-2. |
| 3. Select triangle function, rotate AMPLITUDE c/w, and check U13 pin 10 for a $\pm 1.25V$ triangle. | a. R114, R118 adjustments. b. U13. c. SW13. |

Table 6-3. Output Circuits (Continued)

Indication: Function outputs missing or clipped when TTL sync output OK. Problem with triangle waveform.

| Check | Corrective Procedure |
|---|---|
| 4. Rotate AMPLITUDE cw (MAX), DC OFFSET to OFF, and check 50 Ω OUT (HI) for a 20V p-p (open circuit) triangle. | a. Output amplifier circuit. b. E15, E16 wiring. |
| 5. Check for excessive discontinuities at the triangle peaks near the bottom of a frequency range (other than $\times 1$ to $\times 100$). | a. U5 b. SQW signal at cathode CR10 not $\pm 2.5V$. |
| 6. Check for nonlinearities in the triangle slopes near the bottom of a frequency range (other than $\times 1$ to $\times 100$). | a. Associated timing capacitor or C36 b. U5, CR6 c. Q9, Q10 |
| 7. Check for a waveform symmetry problem. | Go to table 6-8. |

Table 6-4. Sine Conversion

Indication: Sine waveform problem

| Check | Corrective Procedure |
|---|---|
| 1. Set controls to initial positions (refer to paragraph 6-4). | Check for normal operation. |
| 2. Check emitter Q11 for a 4 kHz, $\pm 1.25V$ triangle. | Go to table 6-2. |
| 3. Verify that the ± 1.25 triangle peaks at the emitter of Q11 agree within 3%. | a. R62, R63, R64, R65, R67, R68, R70. b. CR8, CR9, U7 c. $\pm 15V$ supplies |
| 4. Select triangle function; check for $\pm 1.25V$ triangle at U13 pin 10. | Go to table 6-3, step 3. |
| 5. Select sine function; check for $\pm 1.25V$ sine at U13 pin 10. | a. U12 circuitry b. SW12 |
| 6. Check sine distortion 50 Ω OUT (HI) per calibration procedure (refer to table 5-1). | a. R97, R114 adjustments b. Waveform symmetry, R45 adjustment and table 6-8. c. U12 circuitry |
| 7. Check sine amplitude vs frequency per specifications (refer to section 1). | C47, C55, C56, C57 |

Table 6-5. Square Function

| <i>Indication: Square waveform problem</i> | |
|--|------------------------------------|
| Check | Corrective Procedure |
| 1. Set controls to initial positions (refer to paragraph 6-4). | Check for normal operation. |
| 2. Check CR10 cathode for a 4 kHz, approximately $\pm 2V$ square wave. | Go to table 6-2. |
| 3. Select a triangle function, check U13 pin 10 for a $\pm 1.25V$ triangle. | Go to table 6-3. |
| 4. Select square function, check U12 pin 10 for a $\pm 1.25V$ square. | a. Q12, Q13 circuitry. b. SW14. |
| 5. Check square wave at 50 Ω OUT (H1) for the same 20V p-p (open circuit) amplitude as the triangle and sine. | R106, R110, R111. |
| 6. Check rise/fall times of 4 MHz square (50 Ω terminated) for < 50 ns. | C51, C55, C56, C57. |

Table 6-6. TTL Sync Output

| <i>Indication: TTL sync output problem</i> | |
|---|-------------------------------------|
| Check | Corrective Procedure |
| 1. Set controls to initial positions (refer to paragraph 6-4). | Check for normal operation. |
| 2. Check U8 pin 1, for a TTL level, 4 kHz square. | Go to table 6-2. |
| 3. Check U5 pin 8 for a TTL level, 4 kHz square. | a. U8. b. CR11, CR12. |
| 4. Check SYNC OUT TTL. | E27, E28, E19 wiring. |
| 5. Check SYNC OUT waveform at 4 MHz, using a TTL load termination or a $\geq 600\Omega$ resistive termination and ≤ 3 foot RG58U coax. | a. U8. b. E19 ground connection. |

Table 6-7. VCG Circuit

Indication: Generator does not respond correctly to dial and VCG input.

| Check | If Faulty, Check |
|---|--|
| 1. Set controls to initial positions (refer to paragraph 6.4). | Check for normal operation |
| 2. Check for approximately +15V at E11. | a. E10, E11 and E12 wiring. b. +15V supply c. Dial potentiometer |
| 3. Check for 0 ± 5 mV at U1 pin 13. | U1 |
| 4. Check U1 pin 14 for approximately -5V. | U1 |
| 5. Check that as the dial is rotated from 4.0 to .004, the voltage at U1 pin 14 varies from approximately -5 to 0V. | U1 |
| 6. Ensure that U1 pin 5 remains at a constant $0V \pm 40$ mV as the dial is varied. | U1, U4, and U6 circuits. |
| 7. Check that, as the dial is rotated from .004 to 4.0, the voltage at U1 pin 1 does not saturate near -15V or +15V (typical range is between -10V and +10V) and stops varying with the dial. | Q6, U1, and U6 circuits. |
| 8. Check that as the dial is rotated from .004 to 4.0, U6 pin 8 varies from approximately -15V to -10V. | U6, U1, and Q6 circuits. |
| 9. Check that, as the dial is rotated from .004 to 4.0, the voltage at U1 pin 7 does not saturate near +15V or -15V (typical range is between +10V and -10V) and stops varying with the dial. | U4 and U1 circuits. |
| 10. Check that, as the dial is rotated from .004 to 4.0, U4 pin 13 varies from approximately +15V to +10V. | U4 and U1 circuits. |
| 11. Check for nonlinearity in the ± 1.25 V triangle at the emitter of Q11 near the bottom of the $\times 1K$ through $\times 1M$ ranges. | a. Associated timing capacitors or C36. b. U5, Q8 c. Q9, Q10. |
| 12. Check frequencies of $\times 1K$, $\times 10K$ and 100K ranges. | a. Adjust R19. b. C30, 31 and 32 (trimmed by Q20). |
| 13. Check frequency and linearity of $\times 1M$ range. | a. C34 b. C36 nominal value c. Q18, 19, 20 and 21. |
| 14. Check frequencies of $\times 1$, $\times 10$ and $\times 100$ ranges. | R86 and table 6-9. |
| 15. Select log mode. Check that as the frequency dial is rotated from 4.0 to .0004, U3 pin 4 varies from approximately -65V to -45V. | a. U3 b. U1 circuit. |

Table 6-8. Symmetry

| <i>Indication: Waveform symmetry problem.</i> | |
|--|--|
| Check | If Faulty, Check |
| 1. Set controls to initial positions (refer to paragraph 6.4). | Check for normal operation. |
| 2. If symmetry problem appears on $\times 1$, $\times 10$, $\times 100$ ranges only, problem may be R90 adjustment or go to table 6-9. | |
| 3. Perform steps 5 through 12 of table 6-7, then return to this table. | a. R49 adjustment. b. R45 adjustment. |
| 4. Verify RUN signal at cathode CR6 is approximately $+3.5V$. | Go to table 6-10. |
| 5. Verify U6 pin 4 and U6 pin 15 vary from approximately -10 to $-15V$ as dial is rotated from 40 to 004. | U1, U6, R52, R53. |
| 6. Verify amplitude of SQR signal at cathode CR10 is approximately $\pm 2V$. | a. Q7 circuit. b. U7 circuit. c. $+5V$ supply. |
| 7. Check U5, CR6. | |

Table 6-9. Capacitance Multiplier

| <i>Indication: Problem on bottom frequency ranges only.</i> | |
|---|--|
| Check | Corrective Procedure |
| 1. Set controls to initial positions (refer to paragraph 6.4). | Check for normal operation on $\times 1K$ range. |
| 2. Check for 0 Vdc at U11 pins 2 and 6. | SW2 - SW4. |
| 3. Check for approximately 0 Vdc at U11 pin 12. | U11 circuitry. |
| 4. Check for 0 Vdc ± 5 mV at U11 pin 10. | a. R90 adjustment. b. U11 circuitry. |
| 5. Select $\times 100$ range, check U11 pin 10 for heavy oscillations. | C46, U11. |
| 6. Check that the signal at U11 pin 2 is amplified by approximately 6 at pin 12 (within saturation limits). | U11 circuitry. |
| 7. Check for the same signal at U11 pins 6 and 7 as at the emitter of Q11. | SW4, U11 circuitry. |
| 8. Ensure that R93 and R94 are shorted in the $\times 100$ range. | SW4. |

Table 6-9. Capacitance Multiplier (Continued)

| <i>Indication: Problem on bottom frequency ranges only.</i> | |
|--|---|
| Check | Corrective Procedure |
| 9. Check 400 Hz frequency (2.0×100) | a. R86 adjustment b. R89, R95, C45. |
| 10. Check 40 Hz frequency (2.0×10) | R93, SW1 |
| 11. Check 4 Hz frequency (4.0×1) | R94 |
| 12. Check symmetry at 0.2×100 ; ensure triangle is linear | a. R90 adjustment. b. U11. c. Leaky C30, C36, C45, C46, CR6, U5, Q9 |

Table 6-10. Trigger Logic

| <i>Indication: Generator trigger and gate mode problems.</i> | |
|--|--|
| Check | If Faulty, Check |
| 1. Set controls to initial positions (refer to paragraph 6-4) | Check for normal continuous operation |
| 2. If generator operates normally in continuous mode, go to step 7 | |
| 3. Check for 0V at U9 pins 2 and 5. | SW9 |
| 4. Check for a TTL low at U10 pin 16. | U9, +5V supply |
| 5. Check for +5V at U10 pin 9. | a. U10 b. CR8, CR15, Q8 c. U5 |
| 6. Check for approximately +3.5V at anode CR6. Check for normal continuous mode operation. | a. CR6, U6, Q8. b. Go to table 6-2 |
| 7. Check that U6 pin 4 and U6 pin 15 vary from approximately -10V to -15V as dial is rotated from 4.0 to 0.04. | a. U6, R52, R53. b. Go to table 6-2 |
| 8. Go to gated mode (CONT depressed, TRIG/GATE released). Check U9 pin 2 for a TTL high. | a. U10. b. SW9, SW11, +5V supply |

Table 6-10. Trigger Logic (Continued)

| <i>Indication: Generator trigger and gate mode problems:</i> | |
|--|--|
| Check | Corrective Procedure |
| 9. Check U9 pin 1 for a TTL high. | a. U9. b. R73, -5V supply. |
| 10. Check U10 pin 10 for a TTL high. | a. U9. b. U10. |
| 11. Check U10 pin 9 for TTL low. | a. U10. b. Q8. |
| 12. Check anode CR6 for approximately -1.5V. | a. CR15, Q8, R78. b. CR6. |
| 13. Check cathode CR6 for approximately -0.7V. | a. U5. b. U6. |
| 14. Check emitter Q11 for 0 Vdc \pm 100 mV. | a. R81 adjustment. b. Q9 - Q11 circuitry. |
| 15. Connect an external TTL signal to TRIG IN connector; check for the inverse of that signal at U10 pin 10. | a. E25, E26. b. CR13, CR14. c. U9, SW10. |
| 16. Press TRIG/GATE switch and check for an approximate 20 ns negative pulse at U10 pin 10 following the low-to-high transition of the external signal (increasing the frequency of the external generator makes this pulse more visible). | a. U9, SW10. b. C29. |
| 17. Remove the external signal and verify that U10 pin 5 goes from high to low when the MAN TRIG switch is held depressed. | a. SW11. b. U10. |
| 18. Release the TRIG/GATE switch (gated) and check that U10 pin 10 goes from high to low when the MAN TRIG switch is pressed. | SW9. |
| 19. Monitor 50Q OUT. triangle function, for 0 Vdc baseline. | R81, R112 adjustments. |
| 20. Press MAN TRIG switch and check 50Q OUT for a continuous triangle while the switch is held. Depress TRIG/GATE switch (triggered) and verify a single cycle output each time the MAN TRIG switch is depressed. | a. U10 or clock signal to U10 from U7. b. C29 (pulse too narrow). |

Table 6-11. Sweep Circuit

| <i>Indication: Sweep or Ramp problems.</i> | |
|--|-----------------------------|
| Check | Corrective Procedure |
| 1. Depress CONT (Sweep) Extend SWP/STOP Check E48 for +4V | a. U1. b. SW2 |
| 2. Depress SWP/STOP Check collector of Q3. 4V peak ramp If ramp amplitude is >4V peak If ramp amplitude is <4V peak | U1, Q3. Q1, Q2 |
| 4. At SWP OUT check for period change of approximately 30 ms to 60s as the TIME control is rotated from full ccw to full cw | Q2, R22 |
| 5. At SWP OUT check for ramp period drift | C4 |
| 6. At E39 with STOP control full cw, ramp amplitude is 4V peak, with STOP control full ccw, ramp amplitude is 0V. | R12, SW1, SW2 |

SECTION 7

PARTS AND SCHEMATICS

7.1 DRAWINGS

The following assembly drawings (with parts lists) and schematics are in the arrangement shown below.

7.2 ORDERING PARTS

When ordering spare parts, please specify part number, circuit reference, board, serial number of unit, and, if applicable, the function performed.

7.3 ADDENDA

Under Wavetek's product improvement program, the latest electronic designs and circuits are incorporated into each Wavetek instrument as quickly as development and testing permit. Because of the time needed to compose and print instruction manuals, it is not always possible to include the most recent changes in the initial printing. Whenever this occurs, addendum pages are prepared to summarize the changes made and are inserted immediately inside the rear cover. If no such pages exist, the manual is correct as printed.

| Drawing | Drawing No. |
|----------------------------|--------------|
| Instrument Schematic | 0004-00-0166 |
| Chassis Assembly | 0102-00-0837 |
| Chassis Parts List | 1101-00-0837 |
| Generator Board Schematic | 0103-00-0835 |
| Generator Board Assembly | 1100-00-0835 |
| Generator Board Parts List | 1100-00-0835 |
| Sweep Board Schematic | 0103-00-0818 |
| Sweep Board Assembly | 1100-00-0818 |
| Sweep Board Parts List | 1100-00-0818 |

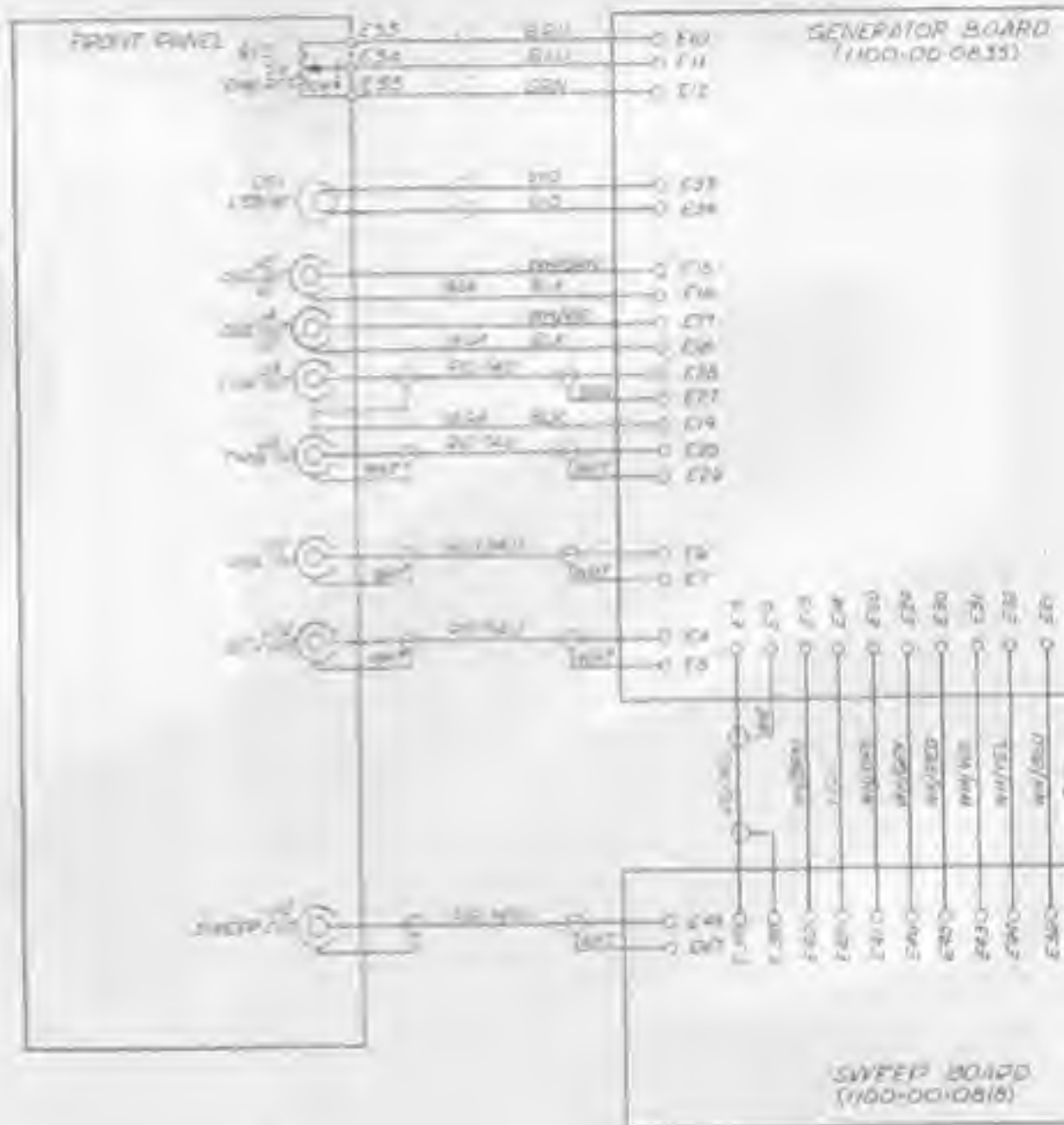
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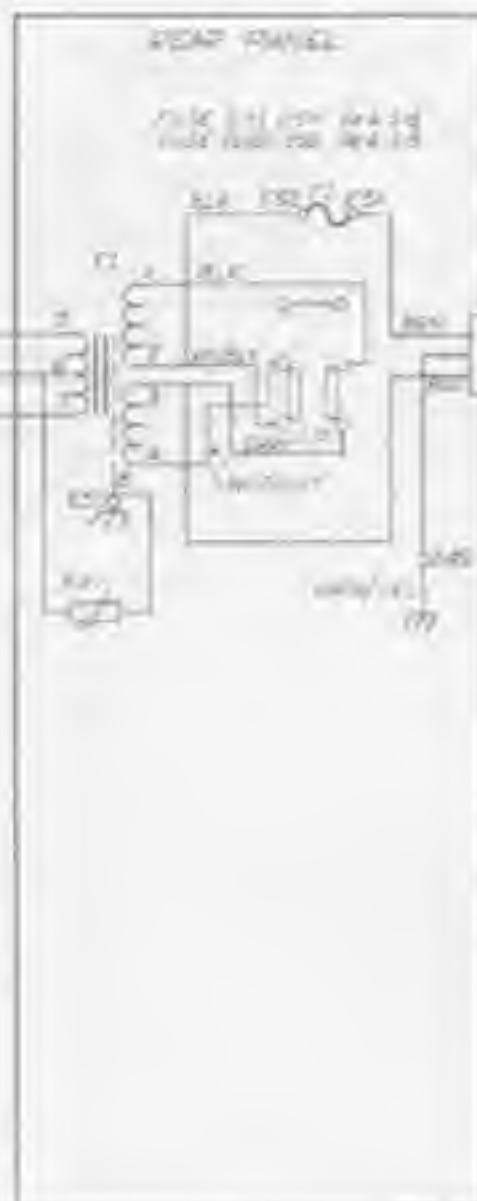
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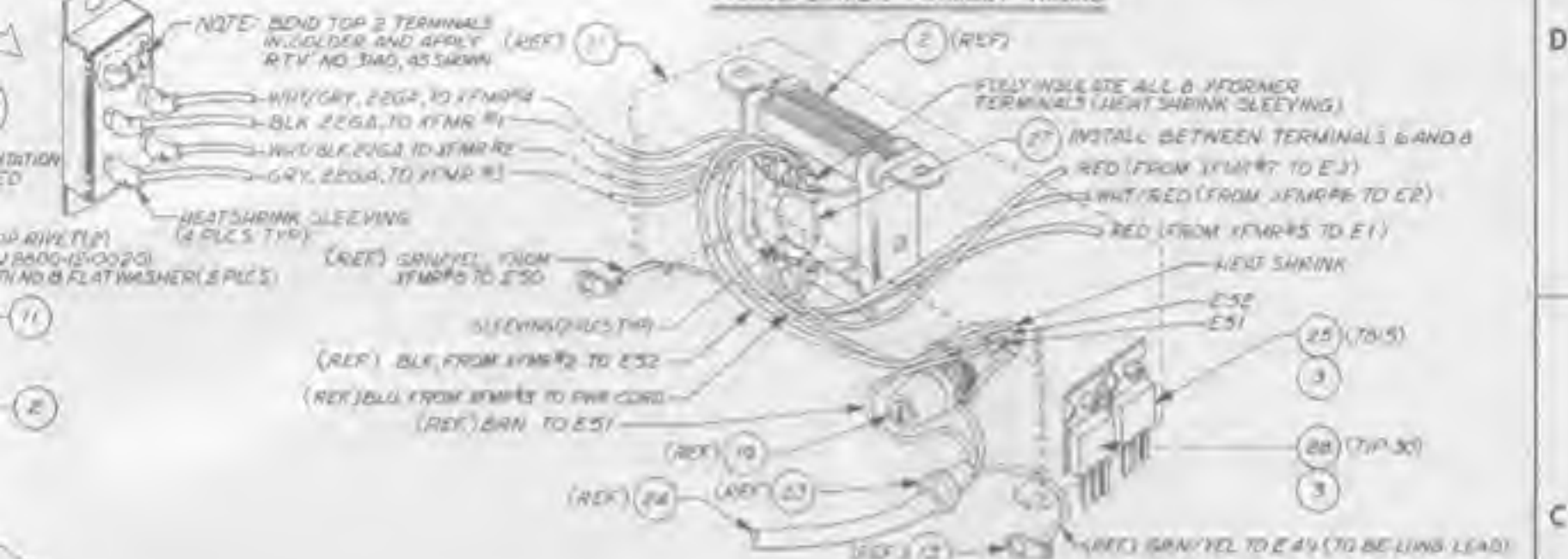
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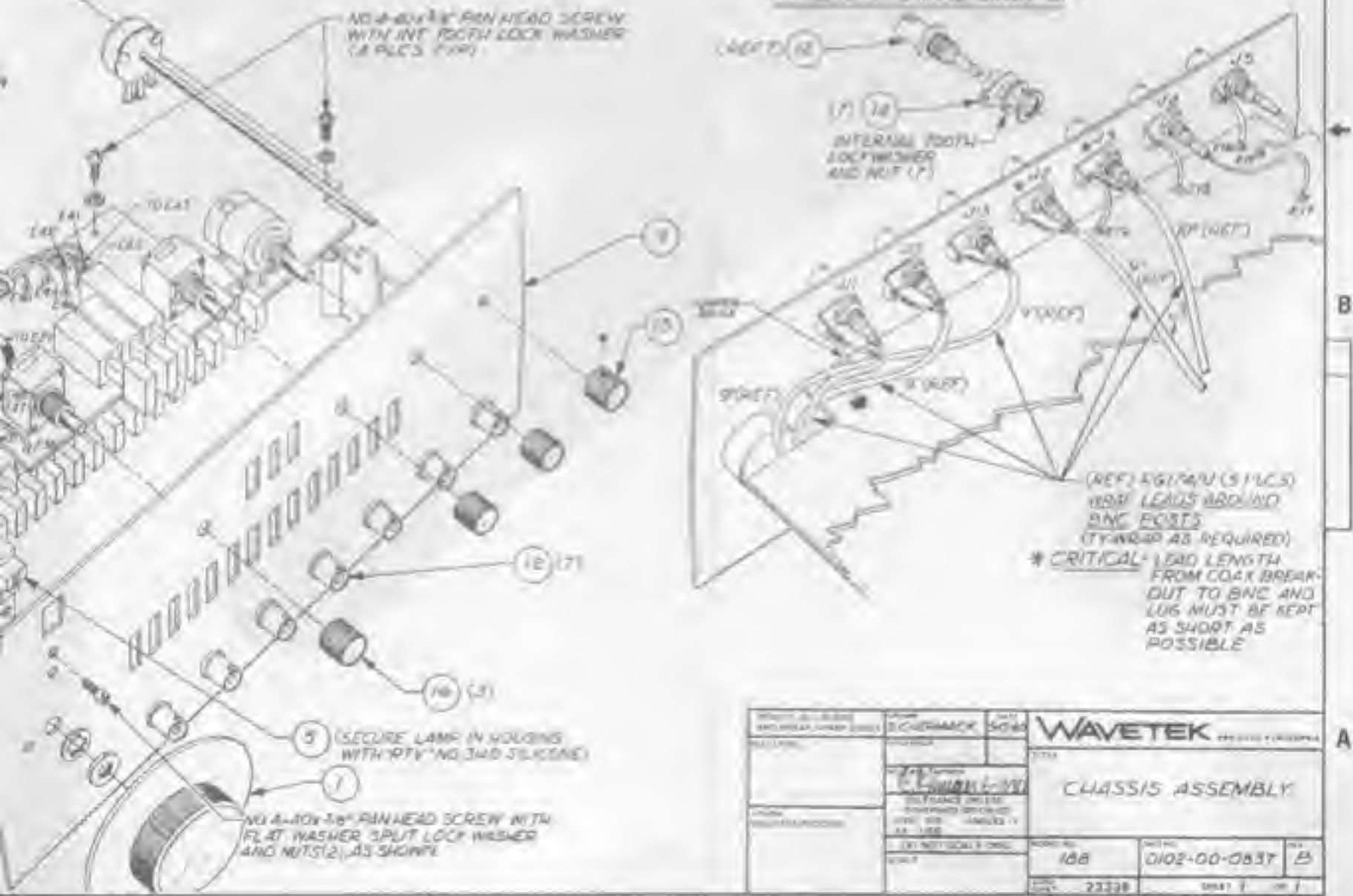
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| 4 | AMERICAN REM-5 550 (10/25/82) | JF | 10/25/82 | |
| 5 | 8-2-86 | HA | 10/86 | |

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NOTE: Do not use overhead projector

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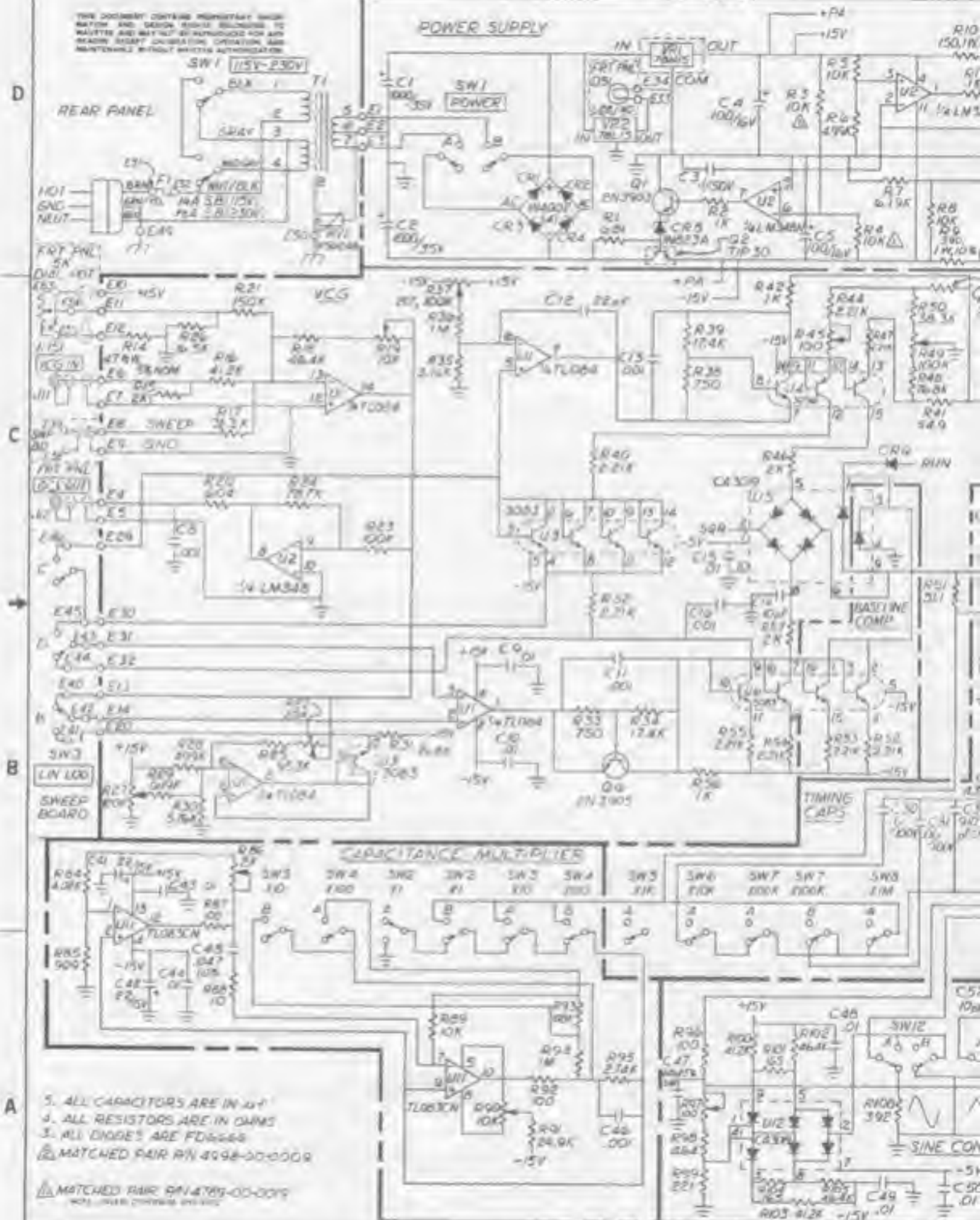
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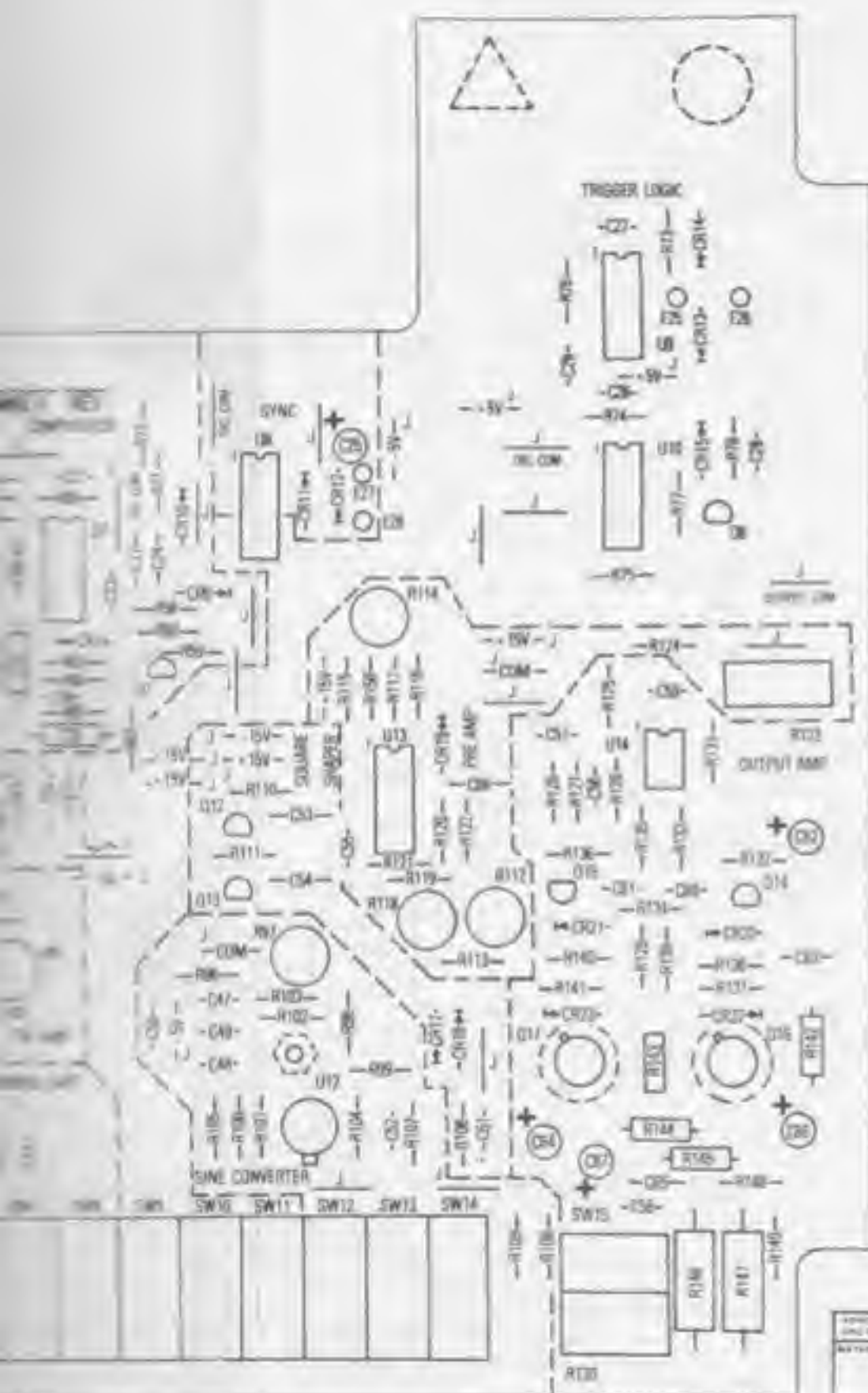
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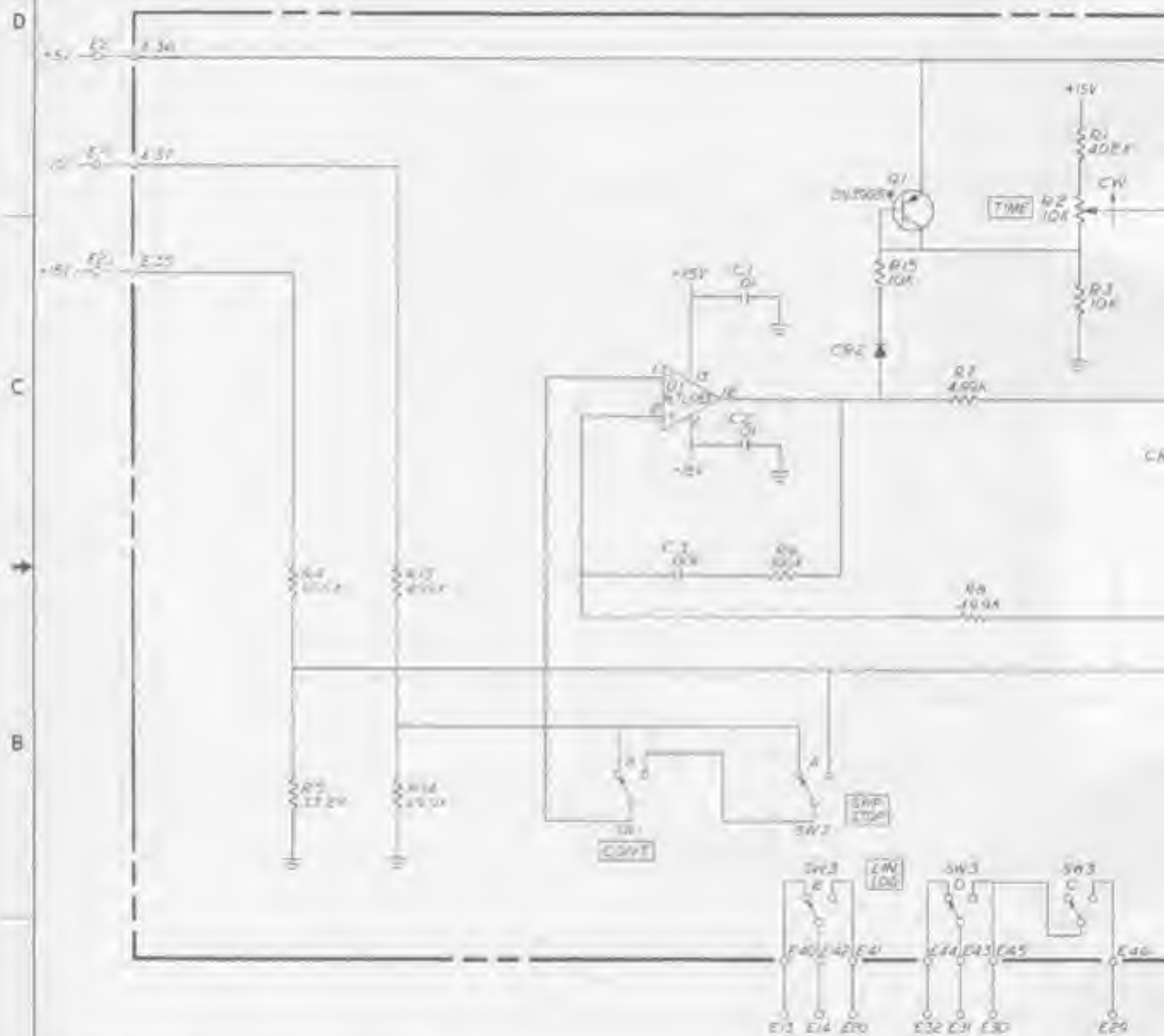
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| QUANTITY 1 | PRICE \$100.00 | TOTAL \$100.00 |
| NAME WAVE TEK | ADDRESS 10000 E. 10th Ave. | CITY DENVER |
| STATE CO | ZIP 80231 | PHONE (303) 751-1000 |
| FAX (303) 751-1000 | E-MAIL WAVE@WAVE-TEK.COM | WEBSITE WWW.WAVE-TEK.COM |

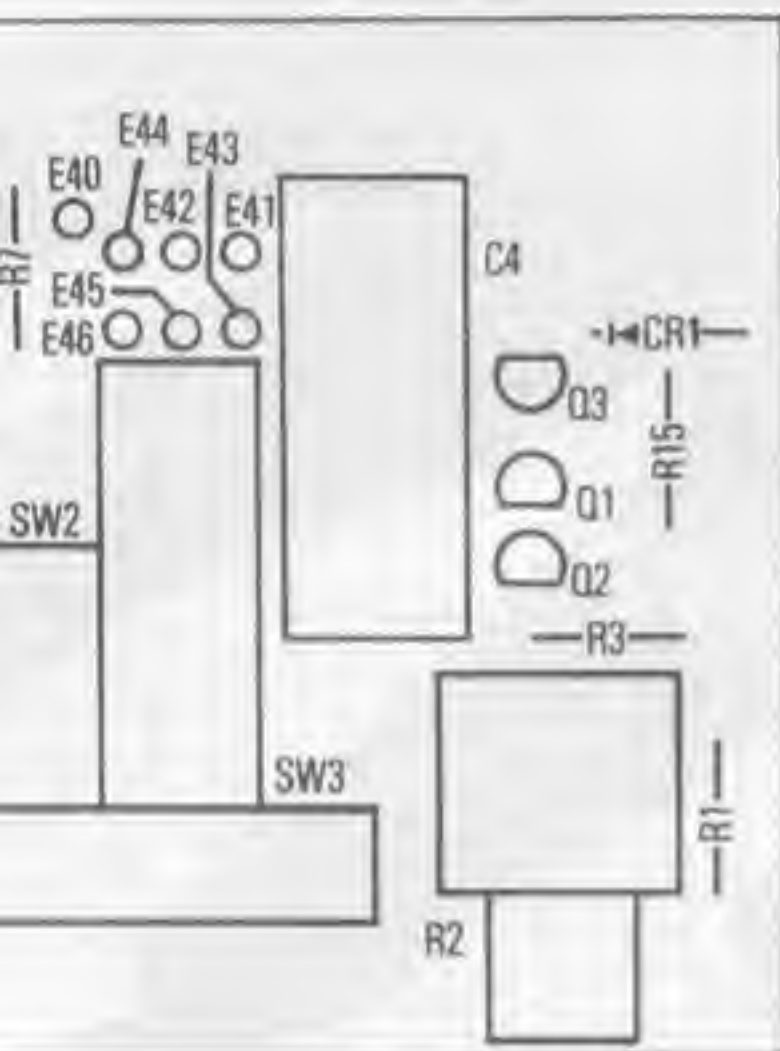
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THIS DOCUMENT CONTAINS PROPRIETARY INFORMATION AND DESIGN RIGHTS. BY ORDER OF THE BOARD OF DIRECTORS, THE INFORMATION CONTAINED HEREIN IS TO BE CONTAINED IN THE DOCUMENT AND NOT TO BE DISCLOSED TO ANY OTHER PERSON WITHOUT THE AUTHORITY OF THE BOARD OF DIRECTORS.

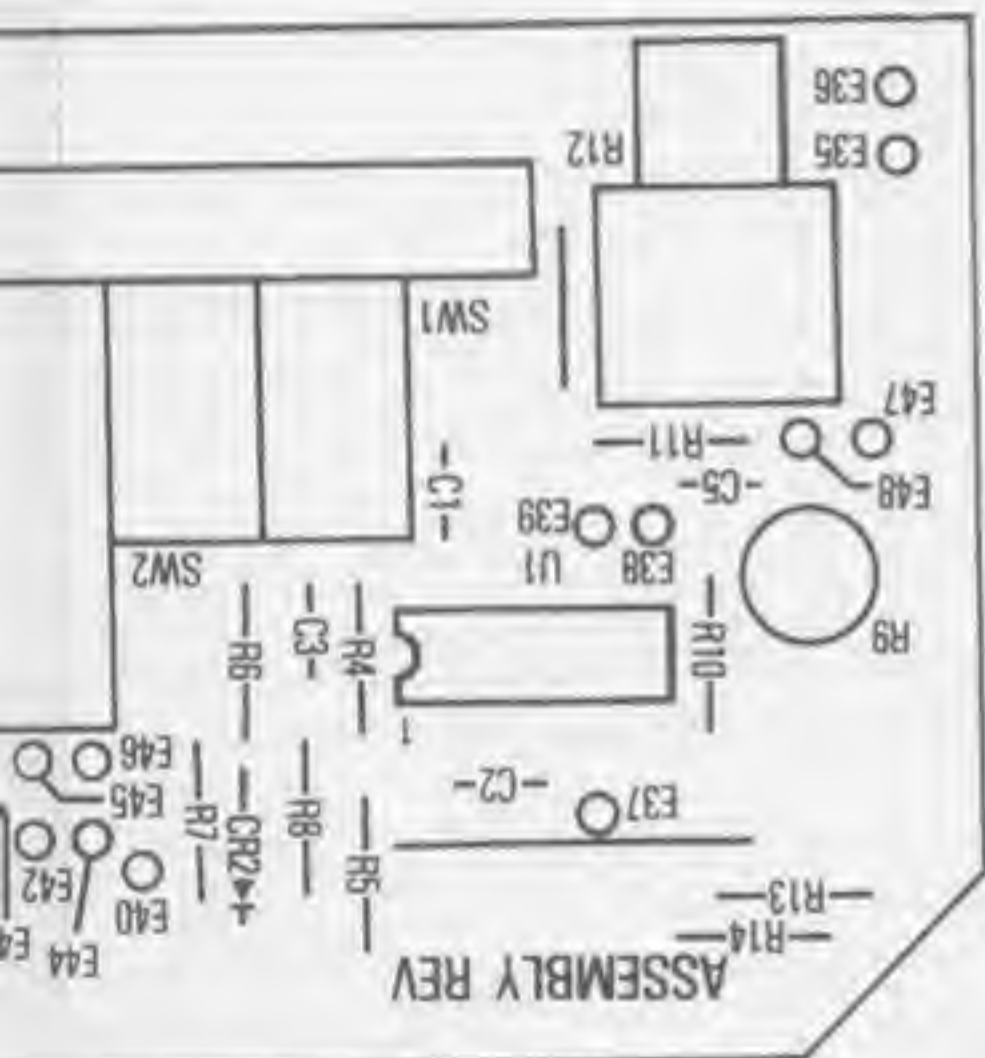


GENERATOR BOARD

1. SWITCHES SHOWN IN "CONF", "STOP", AND "LIN" MODE
2. *MATCHED PAIR: R101, R102, R103, R104, R105, R106, R107, R108, R109, R110, R111, R112, R113, R114, R115, R116, R117, R118, R119, R120, R121, R122, R123, R124, R125, R126, R127, R128, R129, R130, R131, R132, R133, R134, R135, R136, R137, R138, R139, R140, R141, R142, R143, R144, R145, R146, R147, R148, R149, R150, R151, R152, R153, R154, R155, R156, R157, R158, R159, R160, R161, R162, R163, R164, R165, R166, R167, R168, R169, R170, R171, R172, R173, R174, R175, R176, R177, R178, R179, R180, R181, R182, R183, R184, R185, R186, R187, R188, R189, R190, R191, R192, R193, R194, R195, R196, R197, R198, R199, R200, R201, R202, R203, R204, R205, R206, R207, R208, R209, R210, R211, R212, R213, R214, R215, R216, R217, R218, R219, R220, R221, R222, R223, R224, R225, R226, R227, R228, R229, R230, R231, R232, R233, R234, R235, R236, R237, R238, R239, R240, R241, R242, R243, R244, R245, R246, R247, R248, R249, R250, R251, R252, R253, R254, R255, R256, R257, R258, R259, R260, R261, R262, R263, 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| WAVETEK | | 100-00-0818 | |
| SWEEP BOARD | | ASSEMBLY | |
| 188 | | 1100-00-0818 | |
| 23338 | | 100-00-0818 | |



| REFERENCE DESIGNATOR | PART DESCRIPTION | MANUFACTURER | QTY | UNIT PRICE | AMOUNT |
|----------------------|---------------------|---------------------|-----|------------|--------|
| 4000 | 4000-0000-0000-0000 | 4000-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4001 | 4001-0000-0000-0000 | 4001-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4002 | 4002-0000-0000-0000 | 4002-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4003 | 4003-0000-0000-0000 | 4003-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4004 | 4004-0000-0000-0000 | 4004-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4005 | 4005-0000-0000-0000 | 4005-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4006 | 4006-0000-0000-0000 | 4006-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4007 | 4007-0000-0000-0000 | 4007-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4008 | 4008-0000-0000-0000 | 4008-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4009 | 4009-0000-0000-0000 | 4009-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4010 | 4010-0000-0000-0000 | 4010-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4011 | 4011-0000-0000-0000 | 4011-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4012 | 4012-0000-0000-0000 | 4012-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4013 | 4013-0000-0000-0000 | 4013-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4014 | 4014-0000-0000-0000 | 4014-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4015 | 4015-0000-0000-0000 | 4015-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4016 | 4016-0000-0000-0000 | 4016-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4017 | 4017-0000-0000-0000 | 4017-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4018 | 4018-0000-0000-0000 | 4018-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4019 | 4019-0000-0000-0000 | 4019-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4020 | 4020-0000-0000-0000 | 4020-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4021 | 4021-0000-0000-0000 | 4021-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4022 | 4022-0000-0000-0000 | 4022-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4023 | 4023-0000-0000-0000 | 4023-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4024 | 4024-0000-0000-0000 | 4024-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4025 | 4025-0000-0000-0000 | 4025-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4026 | 4026-0000-0000-0000 | 4026-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4027 | 4027-0000-0000-0000 | 4027-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4028 | 4028-0000-0000-0000 | 4028-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4029 | 4029-0000-0000-0000 | 4029-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4030 | 4030-0000-0000-0000 | 4030-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4031 | 4031-0000-0000-0000 | 4031-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4032 | 4032-0000-0000-0000 | 4032-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4033 | 4033-0000-0000-0000 | 4033-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4034 | 4034-0000-0000-0000 | 4034-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4035 | 4035-0000-0000-0000 | 4035-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4036 | 4036-0000-0000-0000 | 4036-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4037 | 4037-0000-0000-0000 | 4037-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4038 | 4038-0000-0000-0000 | 4038-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4039 | 4039-0000-0000-0000 | 4039-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4040 | 4040-0000-0000-0000 | 4040-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4041 | 4041-0000-0000-0000 | 4041-0000-0000-0000 | 1 | 1.00 | 1.00 |
| 4042 | 4042-0000-0000-0000 | 4042-0000-0000-0000 | 1 | 1.00 | 1.00 |

[illegible]

| | | | |
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| | | WAVETEK | |
| | | PARTS LIST | |
| | | SWEEP BD | |
| 188 | 100-00-0B18 | B | |

[illegible][illegible]

| | |
|---|------------------|
| WAVE TEK 10000 PARTS LIST SWEEP BO | |
| 188 2.3338 | 100-00-0818 B |

WAVETEK
SAN DIEGO

9045 Balboa Ave., San Diego, CA 92129
P. O. Box 651, San Diego, Calif. 92112
Tel: 714/279-2200 FAX: 910-395-2007

Bescheinigung des Herstellers/Importeurs

Hiermit wird bescheinigt, daß der/die/das
Funktions-/Wobbelgenerator Modell 188
.....
(Gerät, Typ, Bezeichnung)

in Übereinstimmung mit den Bestimmungen der
1046/1984
.....

(Anbauverfügung)

Funk-entstört ist.

Der Deutsche Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt
und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen
eingetragen.

.....
Name des Herstellers/Importeurs

Wayer
WAVETEK

Electronics GmbH
PRODUCTION
Rudolfsberg 11
D-6250 DORFEN
Tel. (05081) 27 11

Bescheinigung des Herstellers/Importeurs

Hiermit wird bescheinigt, daß der/die/das
Funktions-/Wobbelgenerator Modell 188
.....
(Gerät, Typ, Bezeichnung)

In Übereinstimmung mit den Bestimmungen der
1046/1984
.....
(Anforderung)

Funktionstest ist

Der Deutsche Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt
und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen
eingeführt.

.....
Name des Herstellers/Importeurs

Wayer
WAVETEK

Electronics GmbH
PRODUCTION
Rudolfsberg 11
D-8250 DORFEN
Tel. (08981) 2711

Bescheinigung des Herstellers/Importeurs

Hiermit wird bescheinigt, daß der/die/das

Funktions-/Wobbelgenerator Modell 188

(Gerät Typ Bezeichnung)

in Übereinstimmung mit den Bestimmungen der

1046/1984

(Anschlußverfugung)

funk-tastlos ist.

Der Deutsche Bundespost wurde das Inverkehrbringen dieses Gerätes angezeigt und die Berechtigung zur Überprüfung der Serie auf Einhaltung der Bestimmungen eingetragen.

.....
Name des Herstellers/Importeurs

Wayer
WAVETEK

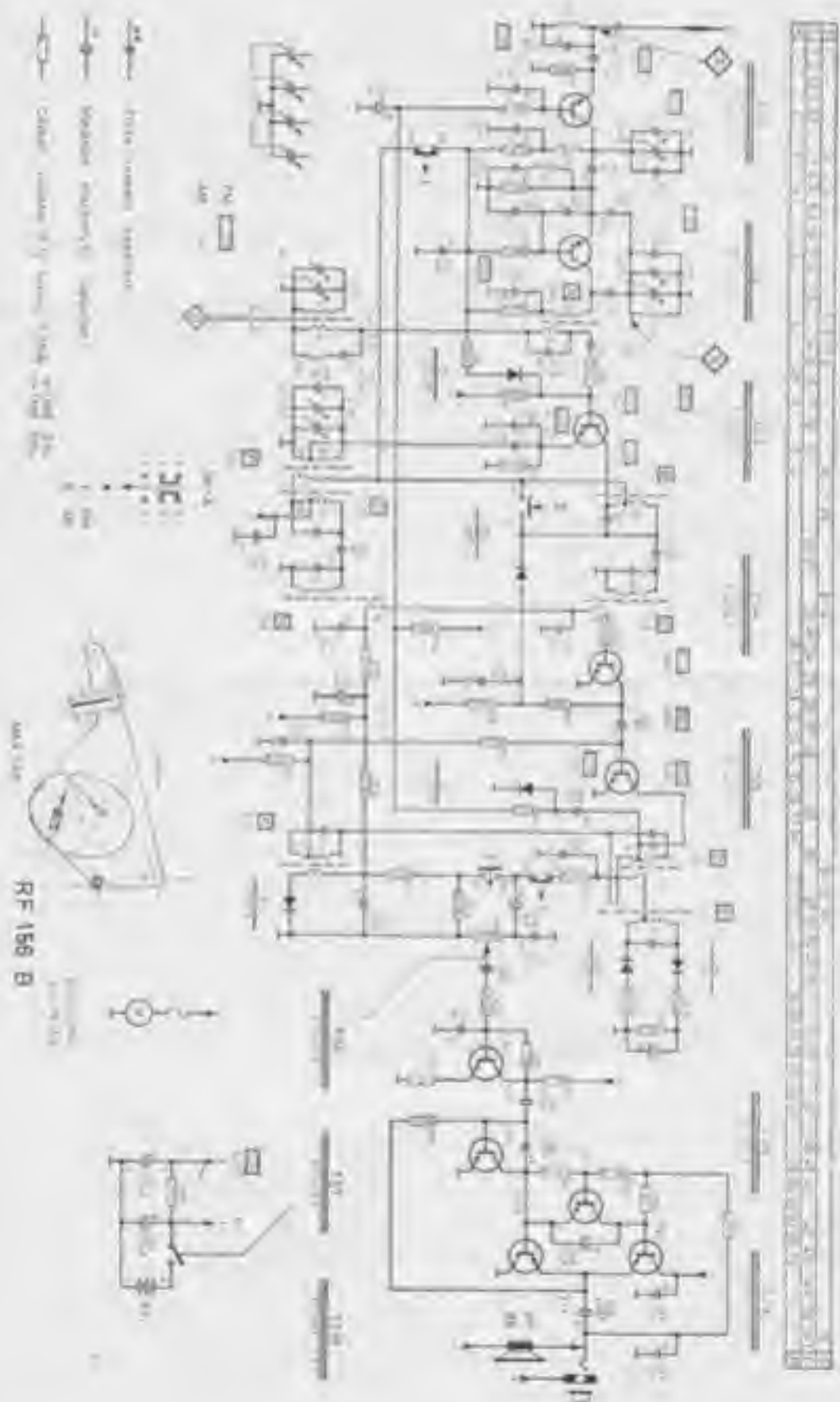
Electronics GmbH

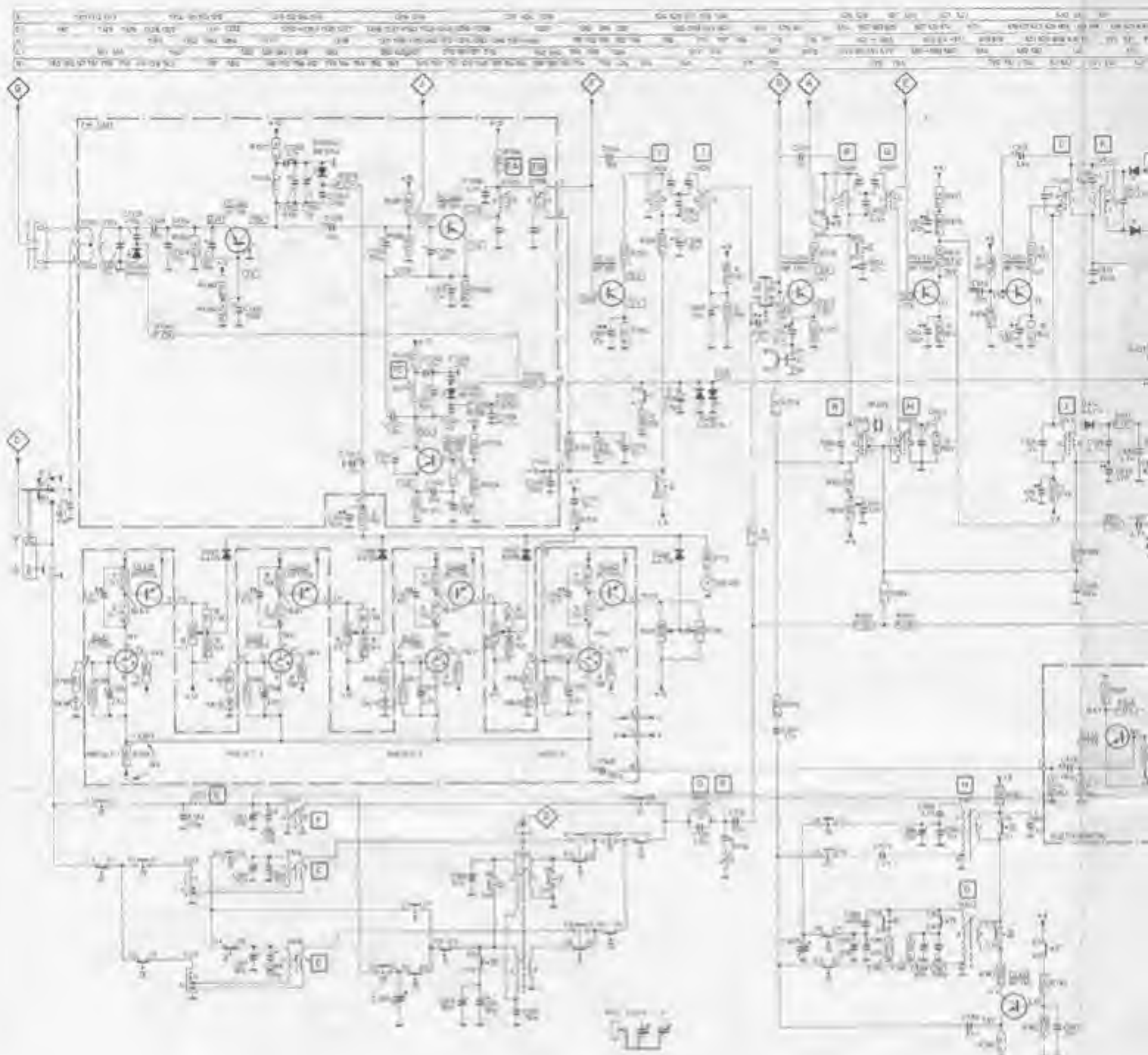
PRODUCTION

Rudolf-Mohr-Str. 11

D-8250 GORFEN

Tel. (089 81) 27 71





CIRCUIT DIAGRAM SHOWS POSITION LW

| | | | |
|--|-------------------------------|---------|-----------------------------|
| | Carbon resistor E24 series | 0.125 W | 5% |
| | Carbon resistor E12 series | 0.25 W | < 1 MΩ 5% > 1 MΩ 10% |
| | Carbon resistor E12 series | 0.5 W | < 1.5 MΩ 5% > 1.5 MΩ 10% |
| | Carbon resistor E12 series | 1 W | < 2.2 MΩ 5% > 2.2 MΩ 10% |
| | Tubular ceramic capacitor | 500 V | |
| | Ceramic capacitor "Pin-up" | 500 V | |
| | Plate ceramic capacitor | | |
| | Flat-foil polyester capacitor | | |

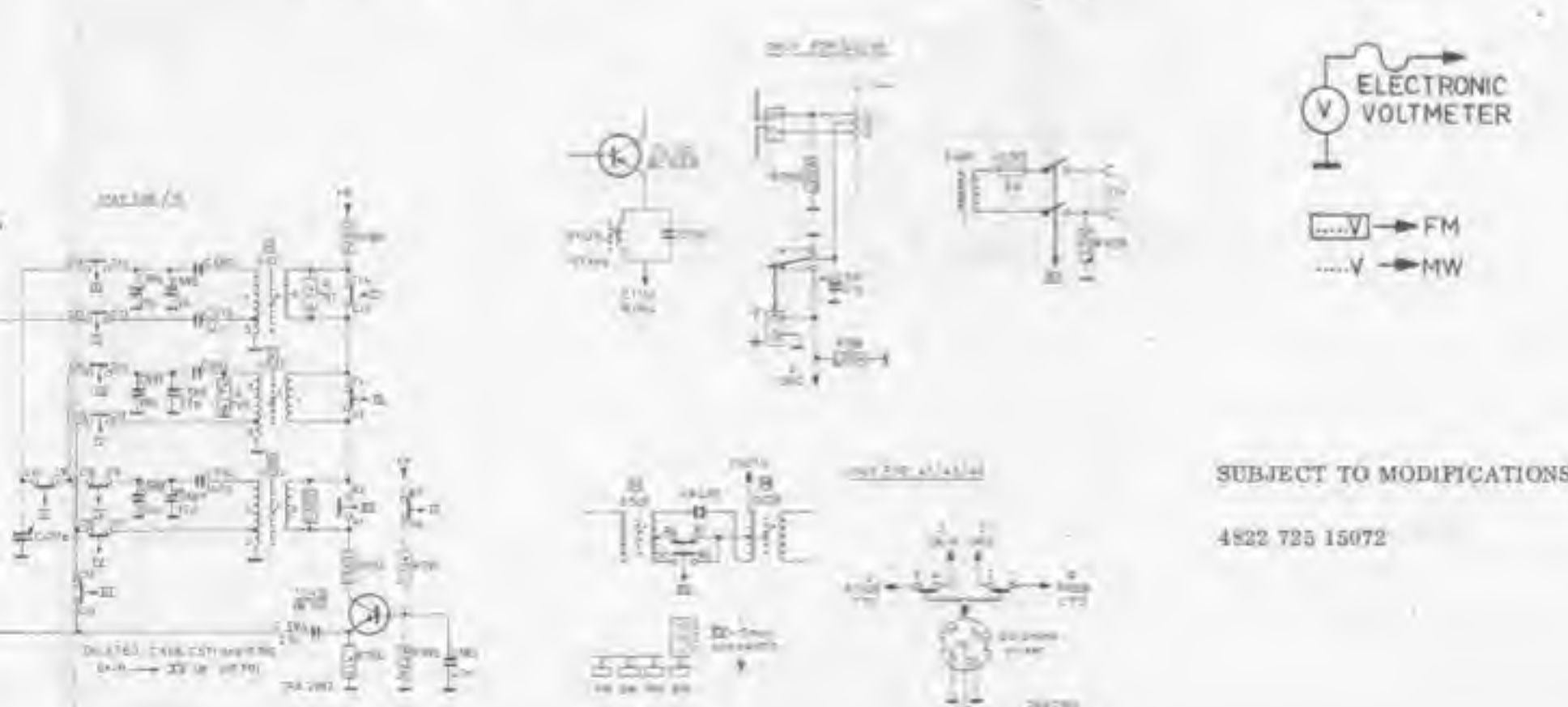
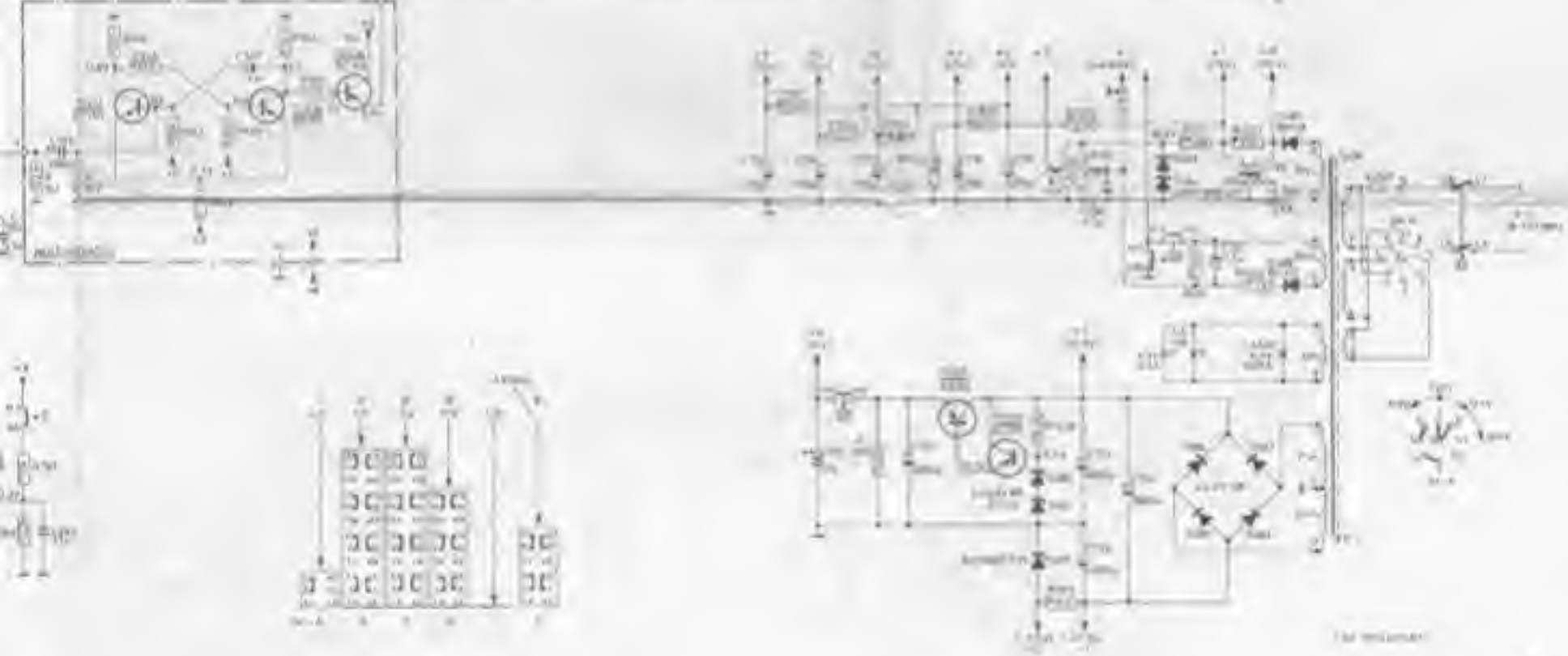
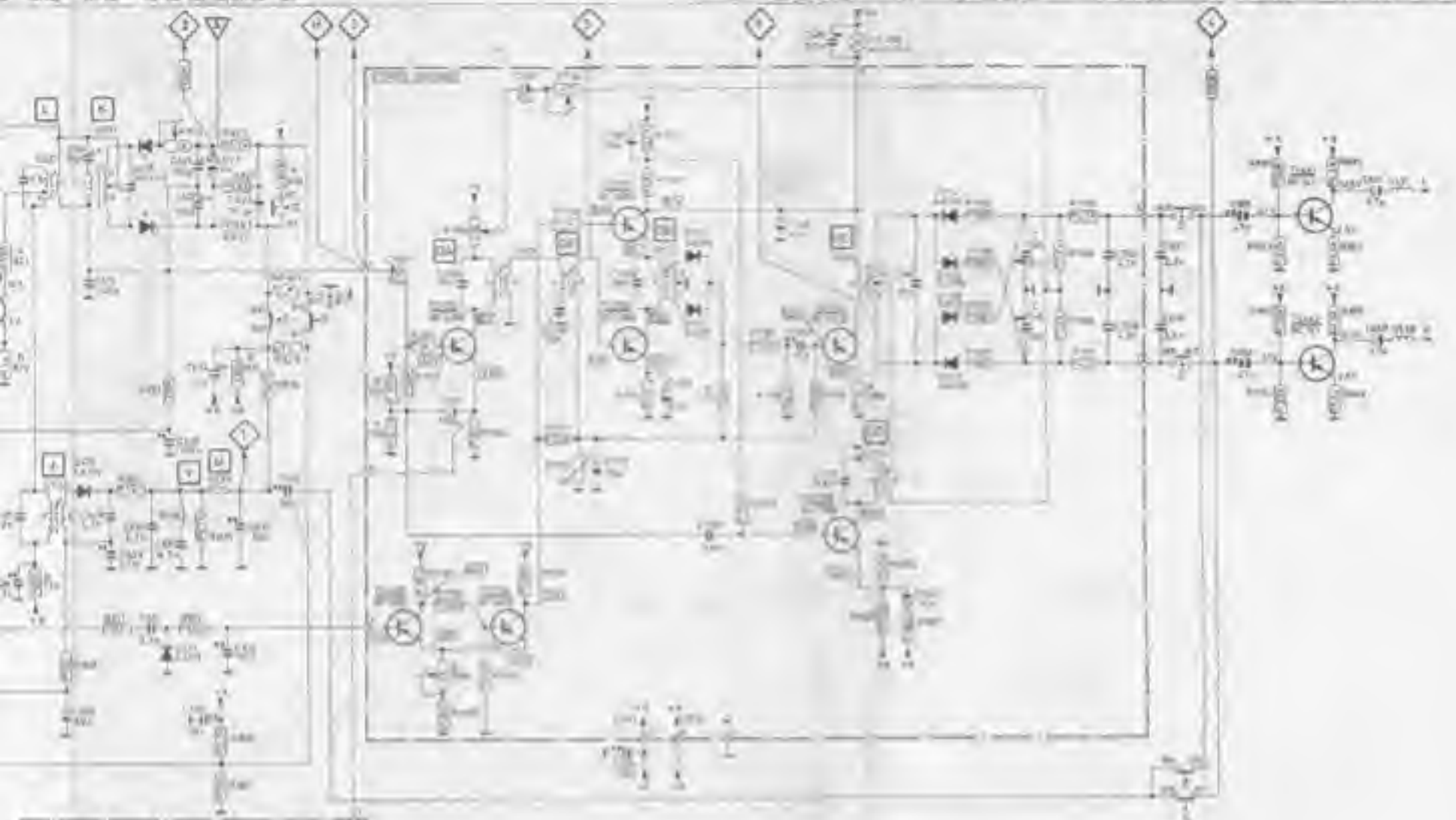
ONLY FOR /16/42/43/66

185 MHz tuner + detector

C1325 becomes 39 pF
C1326 becomes 12 pF
C1337 becomes 2.7 pF
C1340 becomes 370 pF
C1341 deleted
C1344 becomes 2.7 pF
C1352 becomes 3.9 pF
R1371 becomes 3.9 pF
R1383 becomes 1 kΩ

detector;
D472ab, C623, Q624
and IND403 changed
of polarity.

| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 | 37 | 38 | 39 | 40 | 41 | 42 | 43 | 44 | 45 | 46 | 47 | 48 | 49 | 50 | 51 | 52 | 53 | 54 | 55 | 56 | 57 | 58 | 59 | 60 | 61 | 62 | 63 | 64 | 65 | 66 | 67 | 68 | 69 | 70 | 71 | 72 | 73 | 74 | 75 | 76 | 77 | 78 | 79 | 80 | 81 | 82 | 83 | 84 | 85 | 86 | 87 | 88 | 89 | 90 | 91 | 92 | 93 | 94 | 95 | 96 | 97 | 98 | 99 | 100 |
|---|---|---|---|---|---|---|---|---|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|-----|

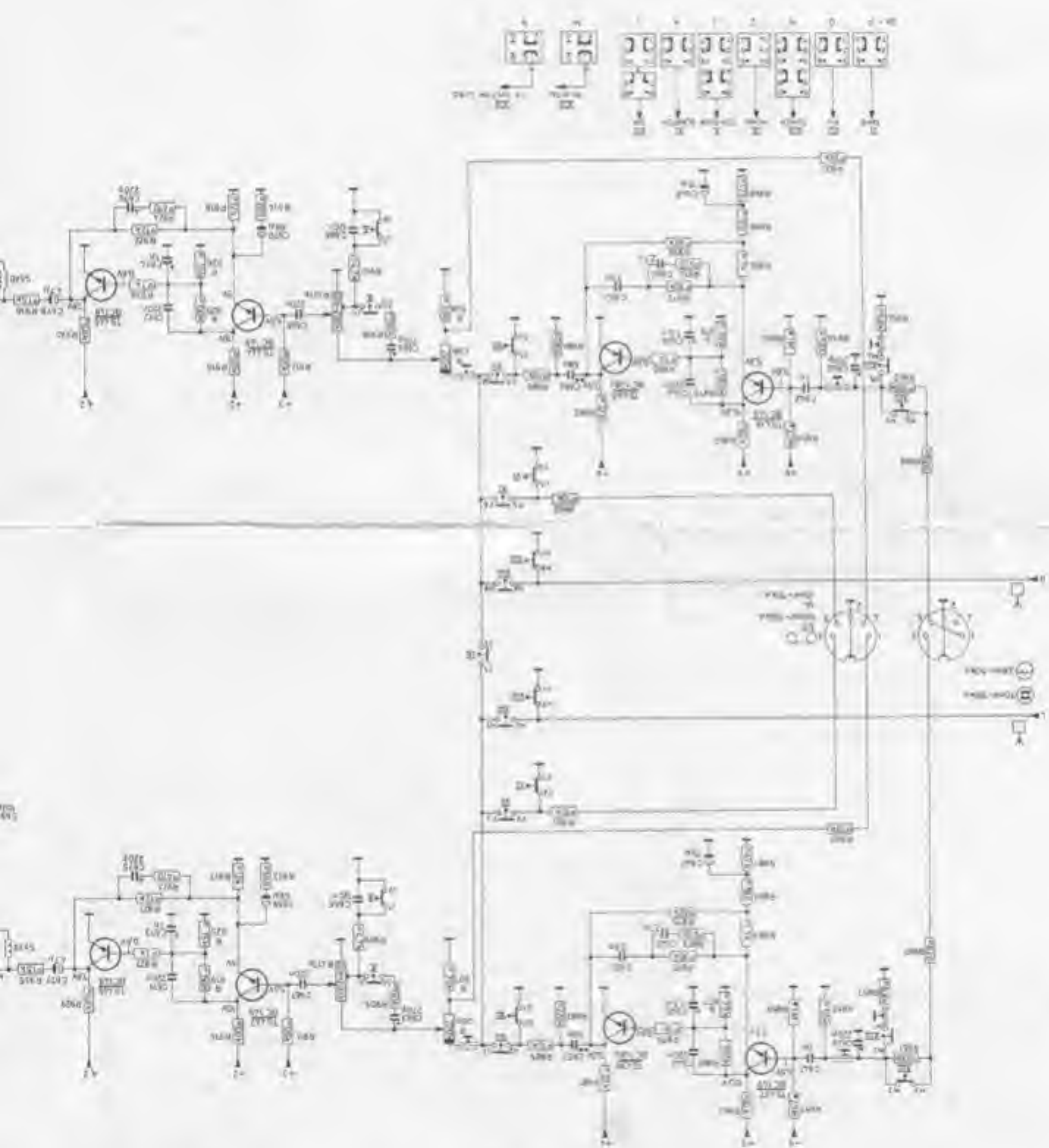


ELECTRONIC
VOLTMETER

FM
MW

SUBJECT TO MODIFICATIONS

4822 725 15072



| | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
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| 5 | 105 | 106 | 107 | 108 | 109 | 110 | 111 | 112 | 113 | 114 | 115 | 116 | 117 | 118 | 119 | 120 | 121 | 122 | 123 | 124 | 125 | 126 | 127 | 128 | 129 | 130 | 131 | 132 | 133 | 134 | 135 | 136 | 137 | 138 | 139 | 140 | 141 | 142 | 143 | 144 | 145 | 146 | 147 | 148 | 149 | 150 | 151 | 152 | 153 | 154 | 155 | 156 | 157 | 158 | 159 | 160 | 161 | 162 | 163 | 164 | 165 | 166 | 167 | 168 | 169 | 170 | 171 | 172 | 173 | 174 | 175 | 176 | 177 | 178 | 179 | 180 | 181 | 182 | 183 | 184 | 185 | 186 | 187 | 188 | 189 | 190 | 191 | 192 | 193 | 194 | 195 | 196 | 197 | 198 | 199 | 200 | 201 | 202 | 203 | 204 | 205 | 206 | 207 | 208 | 209 | 210 | 211 | 212 | 213 | 214 | 215 | 216 | 217 | 218 | 219 | 220 | 221 | 222 | 223 | 224 | 225 | 226 | 227 | 228 | 229 | 230 | 231 | 232 | 233 | 234 | 235 | 236 | 237 | 238 | 239 | 240 | 241 | 242 | 243 | 244 | 245 | 246 | 247 | 248 | 249 | 250 | 251 | 252 | 253 | 254 | 255 | 256 | 257 | 258 | 259 | 260 | 261 | 262 | 263 | 264 | 265 | 266 | 267 | 268 | 269 | 270 | 271 | 272 | 273 | 274 | 275 | 276 | 277 | 278 | 279 | 280 | 281 | 282 | 283 | 284 | 285 | 286 | 287 | 288 | 289 | 290 | 291 | 292 | 293 | 294 | 295 | 296 | 297 | 298 | 299 | 300 | 301 | 302 | 303 | 304 | 305 | 306 | 307 | 308 | 309 | 310 | 311 | 312 | 313 | 314 | 315 | 316 | 317 | 318 | 319 | 320 | 321 | 322 | 323 | 324 | 325 | 326 | 327 | 328 | 329 | 330 | 331 | 332 | 333 | 334 | 335 | 336 | 337 | 338 | 339 | 340 | 341 | 342 | 343 | 344 | 345 | 346 | 347 | 348 | 349 | 350 | 351 | 352 | 353 | 354 | 355 | 356 | 357 | 358 | 359 | 360 | 361 | 362 | 363 | 364 | 365 | 366 | 367 | 368 | 369 | 370 | 371 | 372 | 373 | 374 | 375 | 376 | 377 | 378 | 379 | 380 | 381 | 382 | 383 | 384 | 385 | 386 | 387 | 388 | 389 | 390 | 391 | 392 | 393 | 394 | 395 | 396 | 397 | 398 | 399 | 400 | 401 | 402 | 403 | 404 | 405 | 406 | 407 | 408 | 409 | 410 | 411 | 412 | 413 | 414 | 415 | 416 | 417 | 418 | 419 | 420 | 421 | 422 | 423 | 424 | 425 | 426 | 427 | 428 | 429 | 430 | 431 | 432 | 433 | 434 | 435 | 436 | 437 | 438 | 439 | 440 | 441 | 442 | 443 | 444 | 445 | 446 | 447 | 448 | 449 | 450 | 451 | 452 | 453 | 454 | 455 | 456 | 457 | 458 | 459 | 460 | 461 | 462 | 463 | 464 | 465 | 466 | 467 | 468 | 469 | 470 | 471 | 472 | 473 | 474 | 475 | 476 | 477 | 478 | 479 | 480 | 481 | 482 | 483 | 484 | 485 | 486 | 487 | 488 | 489 | 490 | 491 | 492 | 493 | 494 | 495 | 496 | 497 | 498 | 499 | 500 | 501 | 502 | 503 | 504 | 505 | 506 | 507 | 508 | 509 | 510 | 511 | 512 | 513 | 514 | 515 | 516 | 517 | 518 | 519 | 520 | 521 | 522 | 523 | 524 | 525 | 526 | 527 | 528 | 529 | 530 | 531 | 532 | 533 | 534 | 535 | 536 | 537 | 538 | 539 | 540 | 541 | 542 | 543 | 544 | 545 | 546 | 547 | 548 | 549 | 550 | 551 | 552 | 553 | 554 | 555 | 556 | 557 | 558 | 559 | 560 | 561 | 562 | 563 | 564 | 565 | 566 | 567 | 568 | 569 | 570 | 571 | 572 | 573 | 574 | 575 | 576 | 577 | 578 | 579 | 580 | 581 | 582 | 583 | 584 | 585 | 586 | 587 | 588 | 589 | 590 | 591 | 592 | 593 | 594 | 595 | 596 | 597 | 598 | 599 | 600 | 601 | 602 | 603 | 604 | 605 | 606 | 607 | 608 | 609 | 610 | 611 | 612 | 613 | 614 | 615 | 616 | 617 | 618 | 619 | 620 | 621 | 622 | 623 | 624 | 625 | 626 | 627 | 628 | 629 | 630 | 631 | 632 | 633 | 634 | 635 | 636 | 637 | 638 | 639 | 640 | 641 | 642 | 643 | 644 | 645 | 646 | 647 | 648 | 649 | 650 | 651 | 652 | 653 | 654 | 655 | 656 | 657 | 658 | 659 | 660 | 661 | 662 | 663 | 664 | 665 | 666 | 667 | 668 | 669 | 670 | 671 | 672 | 673 | 674 | 675 | 676 | 677 | 678 | 679 | 680 | 681 | 682 | 683 | 684 | 685 | 686 | 687 | 688 | 689 | 690 | 691 | 692 | 693 | 694 | 695 | 696 | 697 | 698 | 699 | 700 | 701 | 702 | 703 | 704 | 705 | 706 | 707 | 708 | 709 | 710 | 711 | 712 | 713 | 714 | 715 | 716 | 717 | 718 | 719 | 720 | 721 | 722 | 723 | 724 | 725 | 726 | 727 | 728 | 729 | 730 | 731 | 732 | 733 | 734 | 735 | 736 | 737 | 738 | 739 | 740 | 741 | 742 | 743 | 744 | 745 | 746 | 747 | 748 | 749 | 750 | 751 | 752 | 753 | 754 | 755 | 756 | 757 | 758 | 759 | 760 | 761 | 762 | 763 | 764 | 765 | 766 | 767 | 768 | 769 | 770 | 771 | 772 | 773 | 774 | 775 | 776 | 777 | 778 | 779 | 780 | 781 | 782 | 783 | 784 | 785 | 786 | 787 | 788 | 789 | 790 | 791 | 792 | 793 | 794 | 795 | 796 | 797 | 798 | 799 | 800 | 801 | 802 | 803 | 804 | 805 | 806 | 807 | 808 | 809 | 810 | 811 | 812 | 813 | 814 | 815 | 816 | 817 | 818 | 819 | 820 | 821 | 822 | 823 | 824 | 825 | 826 | 827 | 828 | 829 | 830 | 831 | 832 | 833 | 834 | 835 | 836 | 837 | 838 | 839 | 840 | 841 | 842 | 843 | 844 | 845 | 846 | 847 | 848 | 849 | 850 | 851 | 852 | 853 | 854 | 855 | 856 | 857 | 858 | 859 | 860 | 861 | 862 | 863 | 864 | 865 | 866 | 867 | 868 | 869 | 870 | 871 | 872 | 873 | 874 | 875 | 876 | 877 | 878 | 879 | 880 | 881 | 882 | 883 | 884 | 885 | 886 | 887 | 888 | 889 | 890 | 891 | 892 | 893 | 894 | 895 | 896 | 897 | 898 | 899 | 900 | 901 | 902 | 903 | 904 | 905 | 906 | 907 | 908 | 909 | 910 | 911 | 912 | 913 | 914 | 915 | 916 | 917 | 918 | 919 | 920 | 921 | 922 | 923 | 924 | 925 | 926 | 927 | 928 | 929 | 930 | 931 | 932 | 933 | 934 | 935 | 936 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